Education and Science tedmem

Vol 39 (2014) No 174 233-248

The Integration of Nature of Science in the New Secondary Physics, Chemistry and Biology Curricula

Metin Şardağ [1], Sevgi Aydın [2], Nesibe Kalender [3], Selma Tortumlu [3], Murat Çiftçi [3], Şeyma Perihanoğlu [3]

Abstract

One of the important objectives of science education is to have scientifically literate society. Nature of science (NOS) is one of the aspects for raising scientifically literate individuals. In light of this aim, the analysis of new secondary science (physics, chemistry and biology curricula for 9-12 grades, 12 documents in total) curricula would provide valuable information both to related literature, the program developers, and textbook writers. With this aim in mind, in this research the objectives in the new secondary science curricula prepared in 2013 (biology, physics, and chemistry) were analyzed regarding how and to what extend the objectives reflected NOS. In this document analysis study, research group coded the all objectives in the curricula and realized that the number of the objectives highlighted NOS was inadequate. Additionally, some aspects of NOS (imagination and creativity in Science) were ignored. Implications were suggested with help of the results.

Keywords

Nature of science
Secondary science curricula
Document analysis

Article Info

Received: 02.04.2014
Accepted: 05.08.2014
Online Published: 08.06.2014

DOI: 10.15390/EB.2014.3069

Introduction

In this era in which the use of information is more important than having it, scientific literacy as an outcome of science education is stressed all around the world (American Association for the Advancement of Science [AAAS] 1990; National Research Council, [NRC] 1996, 2011; National Ministry of Education [NME], 2013a, 2013b, 2013c; Roberts, 2007; The Organisation for Economic Co-operation and Development [OECD], 2013). Individuals who are scientifically literate should be knowledgeable about nature of science (NOS), how scientific knowledge is produced, and the relation between science-technology and society as well as subject matter knowledge (Shamos, 1995). “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.” (NRC, 1996, s. 22). In the recent science curriculum documents, the processes through which scientific knowledge is produced, NOS, and the features of scientists are highlighted (e.g., AAAS, 1990; NRC, 1996) (Dillon, 2009). In the US, the curriculum document released in 2011 stated that learners should learn about NOS and its aspects (NRC, 2011). Additionally, the relation between the engineering and

[1] Yüzüncü Yıl University, Faculty of Education, Department of Elementary Education, Turkey, metin-sardag@hotmail.com
[2] Yüzüncü Yıl University, Faculty of Education, Department of Secondary Science and Mathematics Education, Turkey, sevgi.aydin45@hotmail.com
[3] Yüzüncü Yıl University, Institute of Education Sciences, Turkey

science is a new aspect that should be mentioned in science courses. As is seen, NOS is a vital element for educating scientifically literate generations. Hence, in many countries all around the world (e.g., US, The Netherlands, South Africa, Great Britain) (Dillon, 2009), NOS is a part of science curricula. To train scientifically literate students who are knowledgeable about NOS, one vital aspect to reach the goal of scientific literacy, to examine to what extend NOS is included in the new secondary science (physics, chemistry, and biology) curricula will provide useful information for the literature and the curriculum developers. Furthermore, the curriculum materials lead textbook authors in determining the content of the textbooks so it has a very important role in this respect. In light of those points, in this study, how and to what NOS extend was integrated into the new secondary science (physics, chemistry, and biology from 9 to 12 grade) curricula were examined.

NOS, Description and its Aspects

In the literature, there has not been a consensus about what NOS is (Abd-El-Khalick & Lederman, 2000a; Abd-El-Khalick, 2001; Irzik & Nola, 2011). McComas, Clough and Almazroa (1998) stated:

> The nature of science is a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors (p.4).

The similar problem exists in the determining the aspects of NOS. Although different researchers and institutions formed aspects of NOS differently, *National Science Teachers Association* [NSTA] lead many studies by releasing a document in which the aspects of NOS were described in 2000. In NSTA (2000) the tentative nature of scientific knowledge (tentativeness), there is no single scientific method, imagination and creativity in science, empirical basis of science, inferential/theoretical nature of science, subjectivity in science, the difference between theory and law, and socio-cultural embeddness of science were presented as aspects of NOS. The short descriptions of those aspects were provided in Table 1.

Table 1. The Aspects of NOS Included in the NSTA (2000) Document and Their Descriptions

Aspects	Description
Tentativeness	Scientific knowledge is not static. It may be produced by the use of new knowledge and technology or the re-interpretation of the existent one.
Scientific method	There is no single method that all scientists use and is followed step by step.
Imagination and creativity in science	In the design of the study, data collection, and the interpretation of the data; in short in all steps of the scientific research, scientists need creativity and imagination.
Empirical basis of science	Science develops though the use of new scientific data. The data are accumulated through observation and experiments, and used as evidence.
Inferential/theoretical	While some parts of scientific knowledge is gathered through experiments and observations, some parts of it is generated though the interpretation of the data collected.
Subjectivity	The scientists' previous life, experiences, and expectations have an influence on what they study, how they observe, how to interpret the data collected, and which data that they focus on.
Theory and law	Theory and law are different from each other and theories do not become laws with increased evidence. While theory is the explanation of a law or a phenomenon how or why it is as it is, law is the description of an order, event or a pattern.
Socio-cultural embeddness of science	The questions focused in research, the observations conducted, and the interpretations made are influenced by the context in which scientists live. The political situation, values of the society and economical conditions determine what, how and to what extend scientists are going to study.

Teaching Nature of Science (NOS)

In the literature, for teaching NOS, there are three approaches, namely, explicit-reflective, implicit, and historical approaches. Implicit approach assumes that students can learn about NOS by simply participating into the scientific activities (e.g., experiment, observation) in the science course. Explicit-reflective approach assumes that students cannot learn about NOS only by experimenting or observation. Therefore, in explicit-reflective approach, NOS and its aspects should be integrated into the course explicitly and those should be addressed through a whole-class discussion at the end of the activities (Abd-El-Khalick & Lederman, 2000a; Khishfe & Abd-El-Khalick, 2002; Lin & Chen, 2002). Akerson, Hanson, and Cullen (2007) examined the effect of explicit-reflective approach on 6th grade science teachers' knowledge about NOS. It was stated that participant teachers enriched their NOS understanding at the end of the summer training. Similar results were received in a study that examined to what extend 2nd graders are able to learn about NOS. Researchers integrated the NOS aspects into the course in two ways, namely, content-embedded (directly related to content) and content-generic (not relating to the content). They also supported those activities by inquiry-based activities. Akerson and Donnelly (2010) stated that although the participants were under a certain level of cognitive development, they were able to grasp the difference between observation and inference, the role of creativity in science, and tentative nature of scientific knowledge.

Khishfe and Abd-El-Khalick (2002) examined the effect of explicit-reflective and implicit approaches that were integrated into inquiry strategy on 6th grade students' NOS understanding. Results revealed that students' NOS understanding in the explicit-reflective group developed more deeply than those of in the implicit approach group. In order to compare and contrast the effect of explicit-reflective approach, Eastwood, Sadler, Zeidler, Lewis, Amiri and Applebaum (2012) studied with 11th and 12th grades students. The development in the students' NOS understating was examined in two different groups whose instructional focuses were different: one is content-driven and the other is socio-scientific issues-driven (SSI-driven). There was no significant difference regarding NOS understanding between the two contexts. However, qualitative analysis showed that students in the SSI-driven group had richer and deeper NOS understanding and were able to provide examples when they talk about NOS. Additionally, researchers highlighted that SSI-driven contexts catalyze the influence of explicit-reflective approach. Schwartz, Lederman, and Crawford (2004) stated that when it is used with explicit-approach, inquiry strategy is another one augmented explicit-reflective approach's effectiveness. Morrison, Raab, and Ingram (2009) examined the factors effective in altering teachers' NOS understanding. According to teachers, the most effective factors were stated as having chance of talking to real scientists, having previous experience about scientific research, and professional development activities that used explicit-reflective approach.

Historical approach includes the teaching NOS by the use of examples in the history of science. Abd-El-Khalick and Lederman (2000a) stated that in order to teach NOS, teachers should integrate interesting events occurring in the history of science (HOS) and make discussions on those special events. In their study, Abd-El-Khalick and Lederman (2000b) stressed the lack of studies focusing on the effect of HOS approach on college students' NOS understanding and stated that the effect of HOS is assumed. To fill this gap in the literature, they conducted a study to examine the effect of HOS course on college students' NOS understating. Results revealed that HOS did not contribute to participants' knowledge about NOS. Researchers tried to interpret this result as the difficulty of integrating HOS into courses to teach NOS and of changing students' perspectives about science in a short time. In another study that used HOS for teaching NOS, Lin and Chen (2002) studied with 63 pre-service chemistry teachers. In this quasi-experimental study with treatment and control groups, the development of participants' NOS understanding was controlled by comparison of pre- and post-test results. The pre-service teachers in the treatment group received an instruction enriched with examples from HOS. Covariance analysis revealed that the mean of the preservice teachers' in treatment group (i.e., with historical examples and discussions on them) was statistically higher than the mean of control group. Furthermore, the interviews conducted showed that pre-service teachers in the treatment group had deeper NOS understanding than those in the control group.

As can be seen from the studies summarized, research has shown that explicit-reflective approach is better than the other ones in teaching NOS (Lederman, 2007). In addition to those approaches, teaching NOS both by integrating the NOS aspects into the content taught (content-embedded) (e.g., teaching tentative nature of scientific knowledge in Atomic Theories topic by the examples of atomic models developed) and without integration them into the topic (i.e., content-generic) (e.g., teaching tentative nature of scientific knowledge by the use of content-free activities) are effective (Lederman, 2007).

In order to ensure teachers' teaching NOS in their teaching, teacher education programs should teach NOS though the use of explicit-reflective approach and content-embedded way (Lederman, 2007). Research has shown that although teachers are knowledgeable about NOS, they have difficulty in integrating NOS into their instruction (Abd-El-Khalick, Bell, & Lederman, 1998). Therefore, it is necessary to support teachers' teaching about science, scientific knowledge, and its nature. In light of the suggestions in the literature, the idea of supporting teachers' teaching NOS through enriching curriculum documents has directed this study. Abd-El-Khalick et al. (1998), Akerson, Abd-El-Khalick, and Lederman (2000) stated that teachers are unable to incorporate NOS into their teaching because of lack of support and inexperience. We think that the explicit statements in the objectives of the curriculum materials, one of the most important elements of instruction, will be useful for teachers in terms of determining in which topics NOS aspects can be taught and to what extend it should be provided. Additionally, Lederman's suggestion for pre-service teacher education in mind, the interpretation of the necessity of explicit and content-embedded integration of NOS aspects in the curriculum objectives forms the basis of this research.

The science standard documents that guide teachers and curriculum developers were examined by McComas and Olson (1998) in order to determine to what extend NOS was integrated into the standards. Researchers analyzed eight international standard documents (i.e., from the US- 4 documents, Australia, New Zealand, England, and Canada) regarding which aspects of NOS were mentioned. Results revealed that some aspects of NOS (e.g., subjectivity in science, the role of creativity in science) were absent in the documents. Another results received was that although the concepts related to NOS (e.g., theory and law relation) was used in the documents, the definition of them were not provided. Additionally, in more than half of the documents, there is no introduction part in which NOS and its aspects were described. McComas and Olson (1998) explained this with authors' lack of consideration about the importance of NOS for learning science. Finally, the researchers highlighted: "[w]e look forward to including a review of science education standards in languages other than English and particularly from non-Western cultures." (p.51). This suggestion leads the research question asked and analysis made in this study.

In Turkey, raising scientifically literate generations is aimed at. Although the curriculum documents provide an introduction part about NOS and its aspects, we think that it is important determine to what extend objectives are related to NOS, how NOS aspects were provided in the objectives (i.e., regarding explicit-reflective vs. implicit approaches), and its relation with the content (i.e., content-generic vs. content-embedded) for revising the documents and their use by teachers. With help of the McComas and Olson's suggestion (1998), this study was carried out in Turkey context and analyzed secondary science curriculum documents (i.e., physics, chemistry, and biology from 9 to 12 grades) regarding a) aspects of NOS, b) the approaches used for providing NOS aspects (i.e., explicit-reflective, implicit, and historical), c) relation to content (i.e., content-generic vs. content-embedded). This study agrees that NOS is viewed as a component of content knowledge in the literature (NRC, 1996). Regarding this point, we think that this research will provide fruitful information about to what degree and how NOS was integrated into new secondary science curricula. The results will be useful for curriculum developers, teachers, textbook writers, and researchers studying on NOS.

Method

Type Of The Study

This study is qualitative in nature, and document analysis that is a qualitative method. Document analysis is the analysis of the documents related to the topic focused on. In conducting document analysis, the borders of the topic studied should be determined clearly and the documents suitable to the nature of the topic should be selected (Yıldırım & Şimşek, 2011). In this study, documents analyzed were the secondary science curricula prepared by NME and The Scientific and Technological Research Council of Turkey. As in stated in the literature review part, with the idea of providing NOS in the curriculum documents explicitly is useful for ensuring teachers' teaching NOS in mind, the curriculum documents were selected and examined.

Although this method that is used in qualitative research frequently and has many advantageous, it also has some limitations. In this method, researchers can collect data about the research topic focused in a short time and with a low budget without any observation and interviews. Additionally, it has some issues regarding sampling bias, shortage of information, and inadequacy in ensuring objectivity in some of the documents. Therefore, it has some weak parts (Bailey, 1982, as cited in Yıldırım & Şimşek, 2011). In order to prevent sampling bias, we examined all curriculum documents for science courses (i.e., physics, chemistry and Biology) at secondary level (i.e., 9 to 12 grades) (i.e., NME 2013a; 2013b; 2013c).

Data Analysis

In this research 1) how and to what extend the aspects of NOS are reflected in curriculum documents, 2) the approaches used for providing NOS aspects (i.e., explicit-reflective, implicit, and historical), 3) the relation to content (i.e., content-generic vs. content-embedded) were analyzed.

Before started to data analysis, the aspects of NOS stated in the NSTA (2000) document, the description, and examples of the aspects were presented to the researcher by the second author. After the meeting that focused on the NOS aspects, the approaches for teaching NOS, and content-NOS relation, researchers started coding. Thus, the trustworthiness of the study was increased by ensuring inter coder reliability (Merriam, 1998).

The codes and categories used for data analysis were taken from the NOS literature (Table 2). The analysis is done though the use of existent codes and categories is called as deductive analysis (Patton, 2002).

Table 2. Codes and Categories Used for Data Analysis

Categories		
Codes used for NOS aspects	Codes used for approaches for teaching NOS	Codes used for content relation
Tentativeness	Explicit-reflective	Content-generic
Empirical basis of science		
Inferential/theoretical	Implicit	Content-embedded
Scientific method		
Subjectivity	Historical	
Imagination and creativity in science		
Theory and law		
Socio-cultural embeddness of science		
Science and technology		

The analysis of physics, chemistry, and biology curriculum documents was conducted by two researchers who are experts both in the field and NOS (i.e., for each field). One of the researchers has a Ph.D. and is an Assistant Professor of Chemistry Education (i.e., the second author). The first author is Ph.D. student who is taking Ph.D. courses. Other researchers are graduate students who are studying for master degree. In total, six coders (i.e., two coders for each field) coded the objectives in the documents. Researchers in each field group coded the objectives independently by the use of codes in table 2. After finishing the coding, they came together to compare and contrast their coding. The inconsistencies were at minimum level. Researchers reached consensus after discussion about the existent differences. When the coders from physics, chemistry, and biology groups faced with a problem, the second author who has experience in science education and qualitative research helped them in coding the problematic objective. Thus, they solved the problems. The analysis results that were received through this striking a balance procedure were summarized by the use of tables and graphs.

In order to ensure better understanding of the coding, example coding was provided in Table 3.

Table 3. Coding of Example Objectives

Field	Objective	Aspect	Approach	Relating to content	Example objectives
Physics	9.1.1.2.c	Inferential/ theoretical	Explicit-reflective	Content-generic	Students are provided to discuss about the relation between observation and inference.
	12.6.1.1.a	Science and technology	Implicit	Content-embedded	Students are provided to interpret physics-technology integration by doing research about imaging technology such as MRI, tomography, ultrasound, and thermal cameras.
Chemistry	9.2.2	Theory and law / Tentativeness	Implicit	Content-embedded	The development of concepts, models, and theories related to the atom is examined by relating the accumulation of scientific knowledge.
	9.4.3.a	Theory and law	Explicit-reflective	Content-embedded	Gas laws are generalizations for gas behavior and the theory is explanation for how gases behave is stressed.
Biology	9.1.1.1.c	Tentativeness/ Science and technology	Explicit-reflective /Historical	Content-generic	The changes in Biology field and knowledge are discussed and researched regarding its relation to other fields and technology.
	10.2.2.3.a	Socio-cultural embeddness of science	Implicit	Content-embedded	Discussions are held by using examples (e.g., genetic engineering, in vitro fertilization, in vitro fertilization, stem cell treatment and their importance for society) that are parallel to the content taught

As can be seen from table 3, some of the objectives include more than one NOS aspect. In this situation, the objective was coded for each NOS aspect separately. Additionally, we observed some objectives in which both historical, and explicit-reflective or implicit approaches were used simultaneously.

Results

In this part of the study, results revealed through the document analysis of secondary level physics, chemistry, and biology curricula (i.e., 9 to 12 grades) regarding how and to what extend the aspects of NOS are reflected in curriculum documents, the approaches used for providing NOS aspects (i.e., explicit-reflective, implicit, and historical), and the relation to content (i.e., content-generic vs. content-embedded) were presented. The results about the existence of NOS in the curricula were summarized in Table 4.

Table 4. The Reflection of NOS into Secondary Science Curricula

Field	Total number of the objectives in the curriculum (grade 9 to 12)	Number of objectives related to NOS (percent)
Biology	341	30 (%9)
Chemistry	503	15 (%3)
Physics	561	26 (%5)

When we look at Table 4, 30 objectives in biology documents (9%), 15 objectives in chemistry documents (3%), and 26 objectives in physics document (5%) are related to teaching NOS and NOS aspects.

The Aspects of NOS in the Documents

The secondary science curricula documents were analyzed in light of the aspects of NOS stated in the NSTA (2000) document. Results were presented in Figure 1.

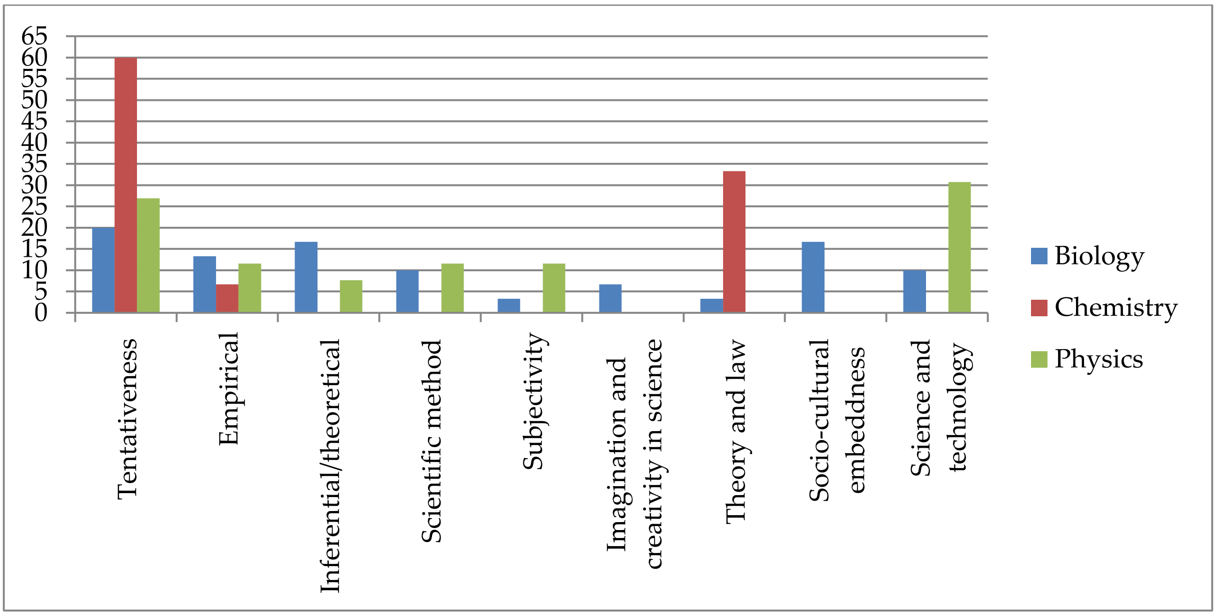

Figure 1. The Percentage of NOS Aspects Mentioned in the Secondary Biology, Chemistry, and Physics Curricula

When the Figure 1 is examined, it can be seen that Biology curriculum documents are better than physics and chemistry ones regarding both the number of the NOS aspects included and the number of the objective related to NOS. In Biology documents, six of 30 objectives (20%) mentioned tentative nature of scientific knowledge aspect whereas minimum stress was made on subjectivity (one objective, 3.3%), and theories and laws (one objective, 3.3%) aspects. When we looked at the Biology document, one of the remarkable points that we realized was the existence of introduction part for NOS and its aspects under the "Basic Skills". Although theories and laws, and creativity and imagination in science aspects were not mentioned in this introduction part, they were mentioned in the objectives.

In chemistry curriculum, when we think about the 15 objectives mentioning NOS aspects, the most frequently identified aspect was the tentativeness (nine objectives, 60%) whereas the least stressed aspect was empirical bases of scientific knowledge (one objective, 6, 67%). No objective mentioning inferential/theoretical nature of science, there is no single scientific method, subjectivity in science, imagination and creativity in science, socio-cultural embeddness of science, and science-technology relation aspects was identified. When we compared the introduction and the objective parts of the document, it can be stated that they are compatible with each other.

In Physics documents that have more objectives (26 objectives) mentioning NOS than chemistry ones, the most frequently cited aspect was science and technology relation (8 objectives, 30,77%) and the least frequently cited one was inferential/theoretical nature of science (2 objectives, 7,69%). No objective mentioning imagination and creativity in science, theories and laws, and socio-cultural embeddness of science was identified. Although NOS and its aspects were mentioned on the objectives, contrary to Biology and Chemistry documents, there is no introduction part for NOS in Physics documents. Some NOS aspects were overlooked in all documents. Those aspects were given in Table 5.

Table 5. The NOS Aspects Ignored in the Secondary Science Curricula

Field	NOS aspects ignored	The number of objectives mentioning the aspect
Biology	Subjectivity	1
	Theory and law	1
	Imagination and creativity in science	2
Chemistry	Imagination and creativity in science	0
	Socio-cultural embeddness of science	0
	Science and technology	0
Physics	Imagination and creativity in science	0
	Theory and law	0
	Socio-cultural embeddness of science	0

Table 5 shows, in Biology document, only one objective was related to subjectivity aspect. Imagination and creativity in science aspect did not appear in Physics and Chemistry ones. Additionally, the ignored aspects in Physics and Chemistry curricula are similar (e.g., socio-cultural embeddness of science, and imagination and creativity in science). The aspect disregarded in all fields was imagination and creativity in science.

The Approaches Used in Emphasizing NOS Aspects in Objectives

The results of the analysis focusing on the approaches used for emphasizing NOS aspects in Turkish secondary science curricula were summarized in Figure 2.

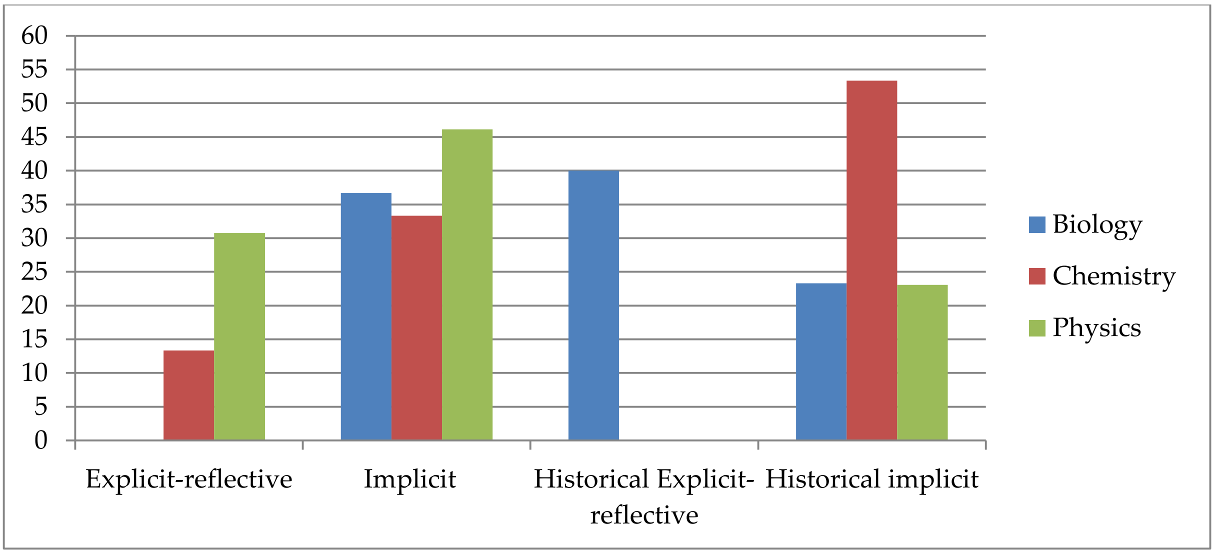

Figure 2. The Approaches Used in Emphasizing NOS Aspects in Secondary Level Biology, Chemistry, and Physics Curricula (%)

As Figure 2 shows, among the objectives related to NOS aspects in Biology curricula (i.e., 30 objectives in total), 11 of them used implicit (36,67%), 12 of them used historical and explicit-reflective (40%), and seven of them used historical approach (23,3%). An example for the use of implicit approach is: *"Students are not made memorized the scientific procedures, they are provided to discover those processes through experimental activities" (Biology, 9.1.1.1.b- Scientific Method).* In this objective, teachers are not provided any suggestion for creating a discussion on scientific method or suggestion for making students understand them explicitly, this objective was coded under implicit approach.

The example of objectives in which historical and explicit reflective approach used: *"The changes in Biology field and knowledge is discussed, and researched regarding its relation to other fields and technology" (Biology, 9.1.1.1.c-Tentativeness/ Science-Technology Relation).* In this objective, it was suggested to discuss two aspects in the classroom.

In addition to those, different than the Physics and Chemistry curricula, no objective that used explicit approach was detected In Biology documents.

Second, when Chemistry Curricula (i.e., 9 to 12 grades, four documents) were analyzed, (i.e., in total 15 objectives mentioned NOS) we saw that two objectives (13,33%) used explicit approach, 5 objectives used implicit one (33,33%), and eight ones used historical and implicit approaches (53,3%). An example of explicit-reflective approach was: *"The difference between theory and law is examined on the basis of NOS."* (Chemistry, 11.3.1.c-Theory –Laws)

For implicit approach: *"The atomic models proposed by Thompson and Rutherford, and the knowledge that scientists have in that era are related in the course."* (Chemistry, *9.2.3a-* Tentativeness)

Example for hybrid use of historical and implicit approach is: *"Students are made compare and contrast the view of matter in ancient and modern time."* (Chemistry, 9.1.1-Tentativeness)

Finally, when the Physics documents were analyzed, in total 26 objectives mention NOS, eight of the objectives employed explicit-reflective approach (30,77%), 12 of them employed implicit (46,15%), and six of them employed historical and implicit ones simultaneously (23,08%). One of the examples for explicit-reflective one was: "Students are provided to discuss the difference between observation and inference." (Physics, 9.1.1.2.c- Inferential/ theoretical)

For implicit approach: "*Students are provided to interpret physics-technology integration by doing research about imaging technology such as MRI, tomography, ultrasound, and thermal cameras.*" (Physics, *12.6.1.1.a-* Science and technology relation)

For historical and implicit approach: "*Students are provided to discuss on the different meanings of force concept through the history of science.*" (Physics, 9.3.2.1.c- Tentativeness)

The Analysis of Objectives Mentioning NOS regarding the Content Embeddness

The summary of the analysis focusing on the content embeddness of the objectives in secondary science curricula was provided in Figure 3.

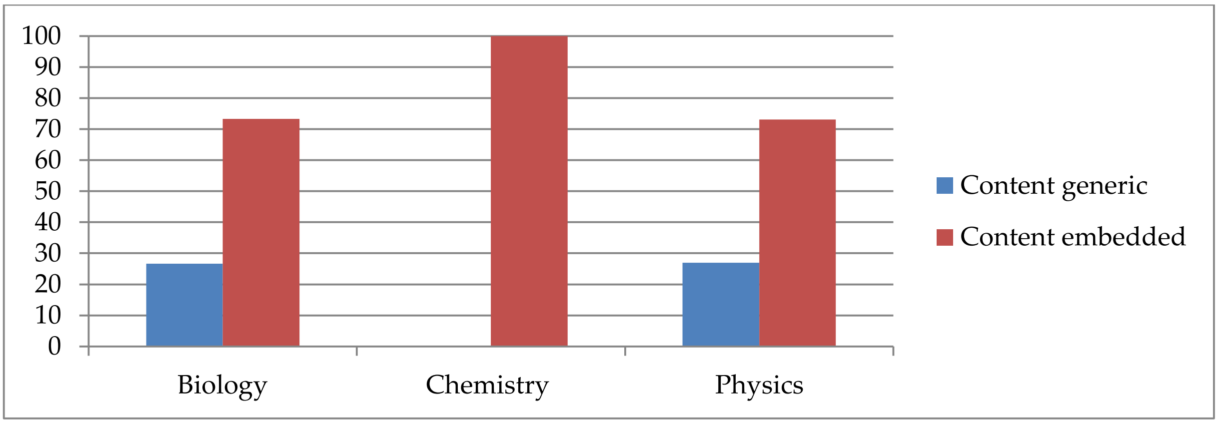

Figure 3. The Content Embeddness of the Objectives Mentioning NOS in Secondary Biology, Chemistry, and Physics Curricula (%)

When we looked at the Figure 3, 22 objectives over 30 in Biology documents, 15 objectives over 15 in Chemistry, and 19 objectives over 26 ones in Physics documents, (in total 56 objectives) NOS aspects were integrated in a content-embedded way. Examples of the objectives as follows:

"The development in the knowledge about cell, and the development microscope and advanced imaging technology in the history are assessed in the science and technology base." (Biology, 9.2.1.2.c- tentativeness/science and technology relation)

"Students are assisted for realizing the development in the symbolic language used in chemistry and its advantageous." (Chemistry, 9.1.3. -Tentativeness)

"Students are provided to understand the development of atom concept through the history and to discuss the importance of Bohr's Atomic Model in this duration." (Physics, 12.4.1.1. -tentativeness)

It is interesting that although Chemistry curricula (9th to 12th grades) did not include any objective that is content generic regarding NOS, in Biology documents eight objectives (26,67%) and in Physics documents seven objectives (26,92%), in total 15 objectives stressed NOS aspect in a content generic way. Some examples of them were given below:

"Empirical nature of science and scientific knowledge, the diversity of the methods used in science, tentative nature of scientific knowledge and the factors affecting the change, subjectivity and objectivity in science, and the popular topics such as science- society relations are discussed by the use of examples from history of biology." (Biology, 9.1.1.1.a. – Empirical, Scientific method, tentativeness, subjectivity, socio-cultural embeddness)

"Students are provided to discuss about the relation between observation and inference." (Physics, 9.1.1.2.c- Inferential-theoretical)

Discussion, Conclusion and Suggestions

In this document analysis research, the secondary science curricula prepared by NME and The Scientific and Technological Research Council of Turkey were analyzed regarding the aspects of NOS and the number of objectives mentioning NOS, the approaches used, and their relation to content were analyzed.

Research in which science curriculum documents in different countries (e.g., McComas et al., 1998), and the textbooks (e.g., Abd-El-Khalick, Waters, & Le, 2008; İrez, 2009) were analyzed regarding NOS has shown that many aspects of NOS are missing (e.g., the role of creativity in science) or non-existent (e.g., there is no single scientific method, tentative nature of Science, socio-cultural embeddness of science). Likewise, analysis conducted in this study (results part, table 5), we showed that the role of creativity in science, subjectivity, and socio-cultural embeddness of science were disregarded. In addition to ignorance of some aspects in all fields, some of them were overlooked in different fields. For instance, science and technology relation aspect was non-existent in chemistry document whereas this aspect was stressed adequately in physics document. Highlighting NOS in the curriculum documents and textbooks will ensure students' learning true knowledge about how scientists work, the features of scientific knowledge, and how it is accumulated. However, as Abd-El-Khalick and others (2008), and Niaz (2010) stated, curriculum documents and textbooks are not able to present the real features of scientists and nature of science. The similar situation was seen in our country in light of the results.

Niaz and Maza (2011) highlighted the importance introduction part of the textbooks because they reflect authors' NOS view in their study in which they examined the introduction part of the textbooks regarding NOS. From this point, we showed that especially in Physics curriculum documents do not have any part at the beginning to introduce what NOS is and its aspects whereas Biology and chemistry documents have. In a similar study, McComas and Olson (1998) examined NOS aspects in international science documents and stated that almost half of the documents did not explain what NOS is and its aspects. Another result revealed in our study was that only Chemistry curricula do mention the relation between law and theory explicitly. In the related literature, McComas and Olson (1998) stated that although theory and law concepts were used in the documents, they were not described in them.

Abd-El-Khalick and Lederman (2000a) suggested explicit-reflective way of teaching NOS and its aspects by embedding them into the content. In this study, we realized that in Biology curricula, explicit-reflective and historical approaches were used. Additionally, in two objectives in chemistry documents and in three objectives in physics one was explicit-reflective and content-embedded. In light of the suggestions in the literature, NOS should be reflected into the objectives by the use of explicit-reflective approach and content-embedded way. Therefore, the number of the objectives parallel to the suggestion is not adequate for physics and chemistry documents.

In this study we analyzed the high school science curricula by the use of NOS aspects provided by NSTA (2000). As stated in the literature review part, researchers have not had a consensus on the what NOS is and aspects of NOS. However, like in the NSTA document, although all of the researchers do not agree with them at least many of them approve NSTA statement that is frequently used. Irzik and Nola (2011) stated that 'consensus view' is not able to explain what exactly science is and its nature. They think that it is an inadequate view so they criticized it because of its ignorance of the specific features of some disciplines and of the activities in which scientists participate. From this starting point, they proposed a new view called as 'family resemblance'. Due to the fact that this view is a new one that has not been fully formed in the literature, we did not use it in this study. This situation may be one of the limitations of the study. Another one is that this study does not provide any information about which activities teachers use to teach NOS aspects; how they comprehend objectives including NOS and its aspects.

Curriculum documents are vital for ensuring the unity in education in the countries that they use national curriculum. When we think that the textbooks are written in light of the curriculum documents and the objectives in them, the quality of the objectives becomes more important. Explicit mentioning NOS and its aspects in the objectives will result in a motivating factor for textbook writers. Additionally, they are guide for the implementers of the curriculum, teachers; about what, when, and to what extend to teach the topic. Hence, they will be one of the important factors influencing the achievement in scientific literacy of next generations. NOS that is one of the aspects of scientific literacy should be part of the curriculum documents. Abd-El-Khalick et al. (1998), and Akerson, Abd-El-Khalick, and Lederman (2000) stated that teachers are unable to integrate NOS into their teaching due to inadequate sources. Therefore, in order to both address the inadequacy of the sources and guide teachers, NOS and concepts related to NOS (e.g., theory, law, inference, hypothesis, data, etc.) should be described clearly and explicitly in the curriculum documents.

Abd-El-Khalick and Lederman (2000a) pointed out that NOS teaching should be explicit and reflective. As revealed in the literature, to ensure that teachers understand the objectives mentioning NOS and integrate them into their instruction, explicit explanations should be given. Objectives mentioning NOS implicitly may not be comprehended correctly by teachers, which may result in inadequate teaching NOS. Therefore, the explicit objectives regarding NOS and how they can be taught should be given in the documents. Additionally, when we think about the teachers who have not had any training about NOS, the use of explicit-reflective approach is vital. Furthermore, for those teachers, similar to examples provided for assessment techniques in the documents, some NOS teaching activity examples should be offered in the curriculum. In this way, we think that the inadequacy in the sources for teaching NOS stated by Akerson and her colleagues (2000) can be eliminated to some extend.

After the discussion made on NOS aspects and NSTA's statements (2000) about NOS aspects, the frame was formed to some extend especially in the last decade. With help this frame, they should be included in the new secondary science curricula. Especially the aspects ignored (e.g., there is no one scientific method, tentative nature of scientific knowledge, socio-cultural embeddness of science, etc.) should be added to the revised ones into the appropriate topics and grades.

Finally, in the future research, whether or not there is any development in the reflection of NOS into the curricula (i.e., both elementary and secondary science) has been appeared in the last decade should be analyzed. Research in science education should shed light for the curriculum development. It would be useful to understand which type of developments have been occurred especially after the frequent stress on scientific literacy and NOS. Additionally, how teachers implement the objectives related NOS and how those are presented in the textbooks are also important for science education in our country. The research based on those points will offer essential information to the literature.

References

Abd-El-Khalick, F. (2001). Embedding nature of science instruction in preservice elementary science courses: Abandoning scientism, but… *Journal of Science Teacher Education, 12(3),* 215-233.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82(4),* 417–436.

Abd-El-Khalick, F. & Lederman, N. G. (2000a). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22(7),* 665–701.

Abd-El-Khalick, F. & Lederman, N.G. (2000b). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37(10)*, 1057-1095.

Abd-El-Khalick, F., Waters, M., & Le, A. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching, 45,* 835–855.

Akerson, V.L., Abd-El-Khalick, F.S., & Lederman, N.G. (2000). Influence of a reflective activity-based approach on elementary teachers' conceptions of the nature of science. *Journal of Research in Science Teaching, 37*, 295–317.

Akerson, V., Hanson, D.L., & Cullen, T. A. (2007) The influence of guided inquiry and explicit instruction on K-6 teachers' views of nature of science. *Journal of Science Teacher Education, 18(5),* 751-772. doi: 10.1007/s10972-007-9065-4

Akerson. V. & Donnelly, L. A. (2010) Teaching nature of science to K-2 students: What understandings can they attain? *International Journal of Science Education, 32(1),* 97-124. Doi: 10.1080/09500690902717283

American Association for the Advancement of Science [AAAS]. (1990). *Benchmarks for science literacy: A Project 2061 report*. New York, NY: Oxford University Press.

Dillon, J. (2009). On scientific literacy and curriculum reform. *International Journal of Environmental and Science Education, 4(3),* 201-213.

Eastwood, J. L., Sadler, T. D., Zeidler, D. L., Lewis, A., Amiri, L., & Applebaum, S. (2012). Contextualizing nature of science instruction in socioscientific issues. *International Journal of Science Education, 34(15)*, 2289–2315.

Irzik, G. & Nola, R. (2011). A family resemblance approach to the nature of science for science Education. *Science and Education, 20,* 591-607. doi: 10.1007/s11191-010-9293-4

İrez, S. (2009). Nature of science as depicted in Turkish biology textbooks. *Science Education,*

93, 422–447.

Khishfe, R. & Abd-El-Khalick, F. S. (2002). Influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders' views of nature of science. *Journal of Research in Science Teaching, 39(7),* 551–578.

Lederman, N. G. (2007). *Nature of science: Past, present, and future*. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 831–879). Mahwah, NJ: Lawrence Erlbaum Associates.

Lin, H. & Chen, C. (2002). Promoting preservice chemistry teachers' understanding about the nature of science through history. *Journal of Research in Science Teaching*, 39(9), 773–792.

MEB, (2013a). *Ortaöğretim Biyoloji Dersi (9, 10, 11, ve 12. Sınıflar) Öğretim Programı,* Ankara.

MEB, (2013b). *Ortaöğretim Fizik Dersi (9, 10, 11, ve 12. Sınıflar) Öğretim Programı,* Ankara.

MEB, (2013c). *Ortaöğretim Kimya Dersi (9, 10, 11, ve 12. Sınıflar) Öğretim Programı,* Ankara.

McComas, W.F., Clough, M.P., & Almazroa, H. (1998). The Role and Character of the Nature of Science in Science Education In McComas (Ed.) *The Nature of Science in Science Education: Rationales and Strategies* (3-39), Kluwer Academic Publishers: The Netherlands.

McComas, W.F. & Olson, J.K. (1998). The Nature of Science in International Science Education Standards Documents In McComas (Ed.) *The Nature of Science in Science Education: Rationales and Strategies* (41-52), Kluwer Academic Publishers: The Netherlands.

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. London: Sage.

Morrison, J. A., Raab, F., & Ingram, D. (2009). Factors influencing elementary and secondary teachers' views on the nature of science. *Journal of Research in Science Teaching, 46(4),* 384–403. doi. 10.1002/tea.20252

National Research Council [NRC] (1996). *National Science Education Standards.* Washington, DC: National Academies Press.

National Research Council [NRC] (2011). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

National Science Teachers Association [NSTA]. (2000). *NSTA position statement on the nature of science*. Retrieved January 7, 2014, from http://www.nsta.org/about/positions/natureofscience.aspx

Niaz, M. (2010). Are we teaching science as practiced by scientists? *American Journal of Physics, 78(1),* 5–6.

Niaz, M. & Maza, A. (2011). *Nature of Science in General Chemistry Textbooks,* SpringerBriefs in Education, Volume: 2, p.1-37.

OECD (2013). PISA 2015: Draft Science Framework. Retrieved from http://www.oecd.org/pisa/pisaproducts/DraftPISA2015ScienceFramework.pdf

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Roberts, D. A. (2007). *Scientific literacy/Science literacy*. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research on science education (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum Associates.

Schwartz, R.S., Lederman, N.G., & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88(4),* 610–645.

Shamos, M. (1995). *The myth of scientific literacy.* New Brunswick, NJ: Rutgers University Press.

Yıldırım, A., Şimşek, H. (2011). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri*, (8 Baskı), Ankara. Seçkin Yayınevi.