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DEVELOPMENT OF PRE-SERVICE TEACHERS' UNDERSTANDING OF THE NATURE OF SCIENCE THROUGH AN INTERDISCIPLINARY CURRICULUM: A CASE STUDY

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Abstract. *In the research, the purpose was to implement and evaluate an interdisciplinary curriculum that aimed at developing social sciences pre-service teachers' understanding and knowledge about the nature of science. This research was based on case study design. In order to collect the research data, the methods of observation, interview and document analysis were used. For the analysis of the data, the inductive content analysis approach was applied. The results of the analysis demonstrated that the curriculum implemented had positive influence on the pre-service teachers' understanding and knowledge about the nature of science. In this respect, it was found that the curriculum helped develop the participants' lack of skills and knowledge about the subjects related to "nature of scientific models, nature of observations and values guiding scientists in their work and social lives" included in the content of nature of science. In addition, it was revealed that the pre-service teachers' lack of readiness made the implementation process difficult.*
Key words: *curriculum development, interdisciplinary curriculum, nature of science, teacher education.*

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Introduction

Rapid changes in the field of science and technology, lead to increased knowledge in different fields. Increased knowledge accumulation also brings about a transformation that requires questioning the quality of the produced and shared knowledge. This situation affects the social, cultural and economic activities of the societies. Therefore, it is seen that the targeted knowledge, skills and values that are gained to the students through the curriculum have changed. Among these knowledge, skills and values that are aimed to be gained to the students, it has been determined that the skills such as information literacy, critical thinking, creative thinking and the basic and high level scientific process skills that serve the achievement of these skills have become more important recently.

In this context, in today's education systems, it is pointed out that students' awareness of science and technology should be increased and that it is an evitable part of a curriculum to help students at all education levels from elementary school level to university level understand the nature of science (Tatar, Karakuyu & Tüysüz, 2011). The recent change in the understanding of nature of science has now required individuals in the society not only to have sufficient knowledge about the nature of science so that they can be considered to be science-literate but also to revise and renew their current knowledge (Köseoğlu, Tümay & Budak, 2008; McComas, 1998; Tatar, Karakuyu & Tüysüz, 2011).

It is reported that in the initial phase of the development phase, it is necessary to examine and develop the related understandings of teachers and pre-service teachers, who are expected to reflect the nature of science to the instruction process (Aslan, Yalçın & Taşar, 2009; Capps & Crawford, 2013; Köseoğlu, Tümay & Üstün, 2010; Tufan, 2007). However, the results of national and international studies show that teachers and pre-service teachers do not have sufficient knowledge about this subject and that they have numerous misconceptions and have wrong or insufficient views about it (Abd-El-Khalick & Boujaoude, 1997; Abd-El Khalick, Bell & Lederman, 1998; Aslan, Yalçın &Taşar, 2009; Çınar & Köksal, 2013; Doğan et.al., 2011; Kang, Scharmann, & Noh, 2005; Lederman, 1992; McComas, 1998; Moss, Abramsand & Robb, 2001; Tatar, Karakuyu &Tüysüz, 2011).

Up to now, different approaches or curricula have been tested regarding the teaching of nature of science to overcome the related problems identified and to structure the nature of science appropriately (Akindehin, 1988; Abd-El-Khalick & Lederman, 2000; Doğan et.al., 2011; Köseoğlu, Tümay & Budak, 2008; Köseoğlu, Tümay & Üstün, 2010). It is seen that these approaches, known as history-based, implicit and explicit-reflective, include different specific features in relation to the teaching of nature of science and that most of the related studies were conducted in a single discipline in the field of science education. On the other hand, it is claimed that nature of science also includes such areas as history, sociology, psychology and philosophy (Abd-El-Khalick & Lederman, 2000; Clough, 2006) and that it is shaped on ethical and political bases (Özdemir, 2014). This situation indicates the importance of an interdisciplinary approach which supports meaningful learning in the instruction process and which aims at developing higher-order thinking skills (Erickson, 1995; Loepp, 1999).

Jacobs (1989, p.8) defines interdisciplinary approach as "a curriculum approach that applies the language and methodology based on more than one discipline to examine a theme, issue, problem or an experience". In interdisciplinary approach, there is a need for an instruction process that simultaneously integrates the knowledge, skills and perspectives of different disciplines rather than simultaneously teaching the subjects in these disciplines (Jones, 2009). In this respect, it is pointed out that it is necessary to establish distinct connections between subjects regarding related disciplines (Drake, 2007). In addition, it is stated that it is possible to teach experiences and concepts related to science and social sciences via a holistic approach by drawing attention to the complex and multi-faceted structure of human behavior and of the instruction process and overcoming the disciplinary boundaries (Şimşek & Adıgüzel, 2012). Studies focusing on interdisciplinary teaching demonstrate that this approach is an effective way of increasing academic achievement and motivation, developing higher-order thinking skills and giving meaning to concepts in different fields (Caplinger, 2013; Faulkner, 2012, Guthrie, Wigfield & VonSecker, 2000; Kelly, 2011; Martin, 2011; Spelt, Biemans, Tobi, Luning & Mulder, 2009; Tsui, 1999). In this respect, it is seen that interdisciplinary approach used in teaching different field subjects and concepts could be an alternative approach for the development of understanding of nature of science.

Background to the Problem

In literature, related studies revealed that different teaching approaches and curricula have been implemented in relation to the nature of science (Akerson & Hanuscin, 2007; Bilen, 2012; Bianchini & Colburn, 2000; Capps & Crawford, 2013; Doğan et.al., 2011; Köseoğlu, Tümay & Üstün, 2010; Leblebicioğlu, Metin & Yardımcı, 2012; Schwartz, Lederman & Crawford, 2004; Sevim, 2012; Sevim & Altındağ-Pekbay, 2012), yet it is seen that there is no research on curriculum development based on the interdisciplinary approach. Therefore, there is a need for a curriculum based on the interdisciplinary approach in order for pre-service teachers to understand the nature of science and scientific knowledge and to reflect their knowledge and skills to in-class implementations using appropriate strategies.

In line with this need, first, a need assessment research was conducted (Author, Author & Author, 2014). The participants of this research were third year pre-service science & technology, social sciences and classroom teachers. Also, semi-structured interviews were held with six volunteering pre-service social science teachers. In this research, it was found that the social science pre-service teachers did not have sufficient knowledge and understanding regarding such subjects as "nature of observations, scientific models and classification; tentativeness of scientific knowledge; hypotheses, theories and laws; scientific approach to research; and epistemological state of scientific knowledge" in category of nature of scientific knowledge; "values guiding people in their work and social lives" in the category of characteristics of a scientist and "scientific decisions" in the category of social structure of scientific knowledge. In other words, it was found that there was a need of an interdisciplinary curriculum for the social science pre-service teachers.

In order to meet the needs determined in the research, a curriculum which was designed based on interdisciplinary approach and which aimed to develop social sciences pre-service teachers' understanding of nature of science was implemented and evaluated. In line with this purpose, the following research questions were directed:

- How does curriculum implemented change pre-service teachers' understanding of nature of science?
- What are positive factors leading to a change in pre-service teachers' understanding of nature of science?
- What are difficulties experienced in the implementation process?

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Methodology of Research

Research Model

In the research the case study design one of qualitative research designs, was applied. In case studies, the analysis process could not only focus on one or more than one individual but also allows investigating a phenomenon, school or a curriculum in depth and in a multidimensional way (Patton, 2002; Yıldırım & Şimşek, 2008; Yin, 2003). In the present research, the purpose was to examine how a curriculum regarding the nature of science designed and implemented in an interdisciplinary approach changed pre-service teachers' understanding of nature of science. For this purpose, the case described in this research was function of nature of science curriculum in implementation.

Case: Function of Nature of Science Curriculum in Implementation

The case described in this research was function of nature of science curriculum in implementation. The development of this curriculum is based on an interdisciplinary approach. Interdisciplinary curriculum describes a curriculum approach that applies the language and methodology based on more than one discipline (Jacobs, 1989). In the process of designing the curriculum, first, in line with the needs revealed via the need assessment study (Doğanay, Demircioğlu, & Yeşilpınar, 2014), the learning outcomes and generalizations of the curriculum were determined. In the following phase, the content which was necessary to obtain the 10 learning outcomes and six generalizations determined was formed.

The content of the curriculum included the subjects of "values guiding people in their work and social lives, nature of observations, nature of scientific models, hypotheses, theories and laws". While preparing the content, the concept of "nature of science" was taken as basis and integrated with the fields of history, geography, physics, chemistry, biology and mathematics. Figure 1 presents the visual association network regarding the integrated fields.

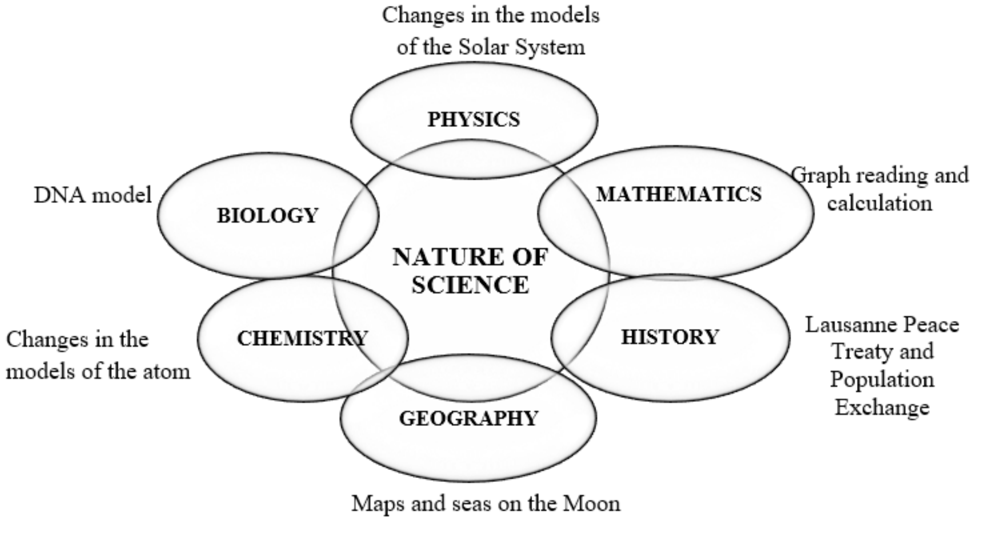

Figure 1. Interdisciplinary visual association network.

While preparing the lesson plans which constituted the basis of the learning and teaching process, the planning process suggested by McTighe and Wiggins (1999) was taken into account. For the implementation of the plans, directive questions and the learning-teaching and assessment activities prepared were used. For the learning-teaching process activities, four worksheets were used, and in the assessment process, two assessment sheets, open-ended questions and a reflective assessment form were used.

General Background of Implementation

The curriculum designed was implemented in eight class hours, in the 2014-2015 Academic Year Spring Semester. The implementation process was carried out in two weeks' time period. The first implementation was carried out on April 14, 2015. The first plan lasted for four lessons and was designed to attain the following learning outcomes: explain the values that guide scientists in their works and social lives; notice that a scientist has characteristics such as imagination, intelligence and honesty; explain the steps of scientific research method; notice that imagination and creativity should be among the methods to be used in research; notice that the results of scientific observations can change to the thoughts of scientists, the ways of scientists use their experiments, the social context in which observations are obtained. The second implementation was carried out on April 21, 2015. The second plan lasted for four lessons and was designed to attain the following learning outcomes: give examples of scientific models used in social and science fields; notice that scientific models are not a copy of the truth; notice that scientific models can change according to time and knowledge; distinguish the difference between the hypothesis, theory and laws associated with different disciplines; explain the relationship between the hypothesis, theory and law by taking account of the examples from different disciplines.

As the social sciences 3rd grade teaching curriculum did not include the course of Nature of Science, the implementation process was conducted within the scope of drama lessons. Following the process, the function of the curriculum in implementation was examined and evaluated in terms of the "change in the understanding of nature of science", "the factors leading to the change" and the "difficulties experienced during the implementation".

Participants

In the research, the convenience sampling method was used. The participants in the research included 25 third-grade pre-service teachers from the department of Social Sciences Teaching at Education Faculty and one of the researchers who developed and implemented the curriculum (implementer-researcher). The reason why the participants were pre-service teachers from the department of Social Sciences Teaching was that the students from this department were those who received the lowest total score (among three departments) from the questionnaire of "Nature of Scientific Knowledge Scale (NKSC) and "Views on Science-Technology-Society (VOSTS) Questionnaire" conducted within the scope of the need assessment study (Author, Author and Author 2014).

For the interviews held at the end of the implementation process, the focus students were determined based on the criterion sampling. The criteria used to determine the participants included participation in the whole process and the participants' levels of participation in lessons. In this respect, the focus students were three female and three male volunteering pre-service teachers, six in total, who demonstrated low, moderate and high levels of participation.

The researcher who conducted the implementation had a master's degree in the field of science teaching and was taking PhD education in the field of curriculum and instruction at the time of the research. The researcher also conducted several studies on science teaching, teacher education and curriculum development during her postgraduate education. Besides the implementation of the curriculum, the researcher took active role together with the other researchers in the process of designing and evaluating the curriculum.

Data Collection and Analysis

In order to collect the research data, the methods of observation, interview and document analysis were used. In the first phase of the data collection process, the curriculum was implemented in a time period of eight class hours in two weeks. In this process, the unstructured observation method was used, and one of the researchers video-recorded the implementation process. Within the scope of document analysis, the reflective assessment forms filled out by the students at the end of each lesson were used. In this form, the students were expected to state and reason what they had learned during the lesson, what knowledge and skills they had acquired to use in their daily lives, in which parts of the instruction process they experienced difficulties, which activities and subjects drew their attention most, and which scientific areas were more associated with what they had learned. Following the observations, semi-structured interviews were held with six volunteering pre-service teachers who

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met the criteria of research. The interview form included 10 questions directed to the students to determine their understanding of the characteristics of scientists as well as their understanding of the nature of scientific knowledge and to identify their views about the implementation process. The interviews were held between 29 May 2015-2 June 2015 by one of the researchers in the researcher's office. Before the interviews, an interview protocol was prepared for the questions that were planned to be asked, and the aim of the interview was shared with the participants. In this process, the participants stated that they would like to participate voluntarily. The interviews with six participants took 15 minutes on average. The interviews and pre-interview procedures were audio-recorded with the permission from participants.

For the analysis of the research data, the inductive content analysis method was used (Patton 2002). In the analysis process, the research data collected via observations, interviews and documents were holistically analyzed. In the first phase, the categories and sub-categories regarding the change in the understanding of nature of science and the factors guiding this change were determined. Following this, the related categories were gathered, and the models describing the situation were formed.

Validity and Reliability Studies

Within the scope of validity studies, first, to ensure content validity, five faculty members expert in the fields of science education and curriculum and instruction were asked for their views about the measurement tools developed. In line with their views, the necessary corrections and changes were done to clarify some of the questions in the reflective assessment form. In addition, the whole research process was presented to expert review (Brantlinger Jimenez Klingner Pugach & Richardson, 2005; Creswell, 2008) to determine the appropriateness of the research design to the research questions directed in the study and to assess the validity of the results obtained. Moreover, methodological triangulation (Brantlinger et.al., 2005; Creswell, 2008; Guba, 1981; Patton, 2002; Yin, 2003) was done, and the data collected in different ways were compared. The findings obtained were supported with direct quotations, and at the end of each quotation, the source of data and the method applied to collect the data were mentioned. For the quotations, such codes as S1 and S2 were used for the focus students, and for the other students, codes such as AB and HA representing the initials of their names were used. Within the scope of the verification for reliability (Guba, 1981), an expert in the field of qualitative research examined the relationship of the categories and sub-categories with the selected raw data texts. Eventually, a consensus was reached on all the categories and sub-categories related to the raw data texts examined in the research.

Ethical Procedures

Research ethics are guiding rules that guide researchers in subjects such as personal privacy, confidentiality of data, participant approval to conduct research in accordance with ethical principles (Berg, 2001; Christians, 2000). Within this scope, participant approval was obtained in the research in line with the voluntary principle, and all participants were informed about the purpose of the research. At all stages of the research, the identities of the participants were kept, and the codes given to the participants were used when quoting raw data texts.

Results of Research

Structure of the Implementation Process and the Change in the Understanding of Nature of Science

Figure 2 presents the categories and sub-categories which were obtained via the analysis of the interviews and observations and which explained both the structure of the implementation process and the change in the understanding of nature of science.

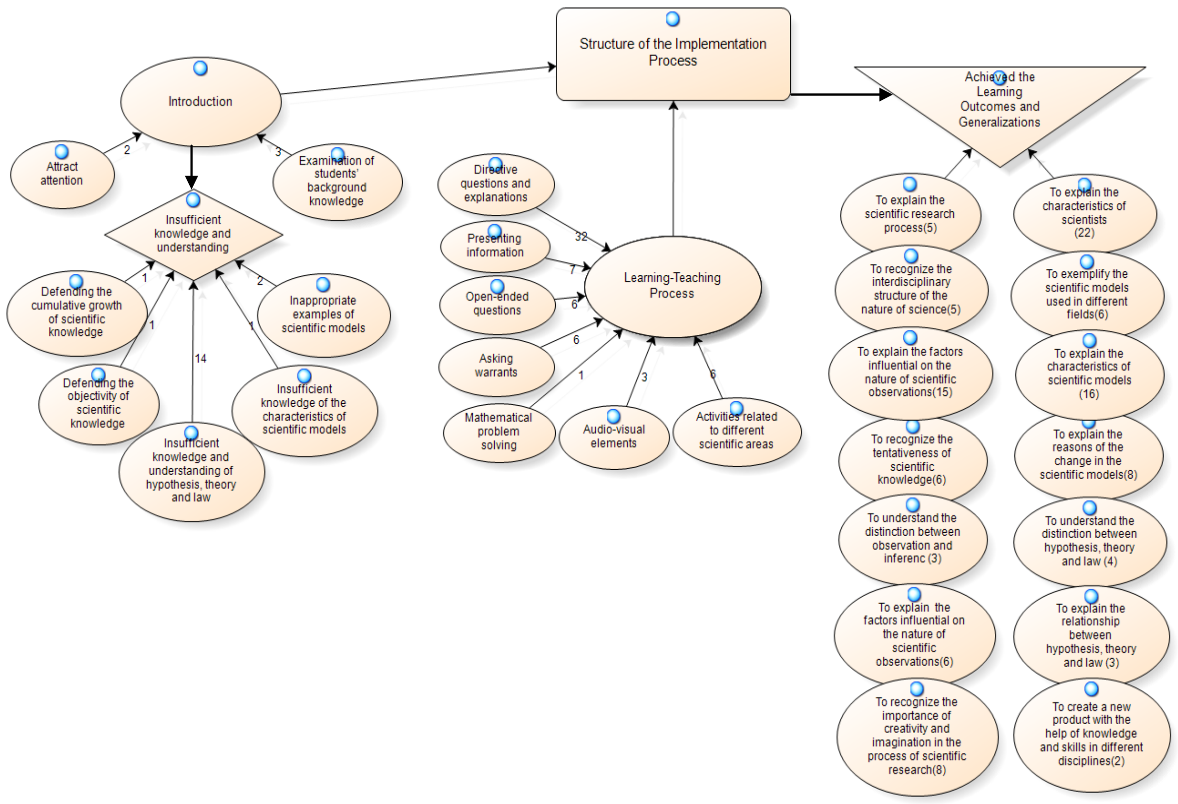

Figure 2. Structure of the implementation process and the change in the understanding of the nature of science.

As can be seen in Figure 2, the implementer-researcher attracted attention and examined the students' background knowledge about the subject using the question-and-answer method. According to the results, the students thought that there was cumulative growth of scientific knowledge and that it was objective; in addition, the students gave inappropriate examples to the scientific model and had insufficient knowledge and understanding regarding such subjects as characteristics of scientific models and hypothesis, theory and law. It was seen that one of the students without much knowledge about the subject was unable to understand the distinction between theory and law:

Law is proved experimentally, and theory is considered to be true without being proved (Observation, 21st April 2015).

Another student claimed that scientific knowledge is objective, saying:

With the development of technology, subjective information turns into objective information… (Observation, 14th April 2015).

For the purpose of overcoming the deficiencies mentioned, it was seen that the implementer-researcher presented information; that the students were asked to give the warrants for their responses; and mathematical problem solving was included in the learning-teaching process. In addition, the implementation process was supported with directive questions and explanations, open-ended questions, audio-visual elements and with activities related to different scientific areas. An example for the directive questions and explanations used by the implementer-researcher can be given as follows:

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> *Well, you all looked at the same things and produced various stories… think that you are scientists, and what did you do in this process? (Observation, 14th April 2015).*

In the implementation carried out in the second week, the implementer-researcher presented information about scientific models as follows:

> *We can consider each of these maps, you use in your field, as a scientific model. If we have a look at what modelling is, well, we can define it as the whole of activities carried out to make an unknown target clear and comprehensible with the help of current sources. As for the model, it is … (Observation, 21st April 2015).*

It was seen that in another dimension of the category and the related sub-categories, the pre-service teachers achieved the learning outcomes and generalizations to a great extent as a result of the introduction and learning-teaching process activities. In this respect, according to the observations and interviews, the pre-service teachers managed to explain the scientific research process (f:5), the characteristics of scientists (f:22), the characteristics of scientific models (f: 16) and the reasons of the change in the models (f:16), the factors influential on the nature of scientific observations (f:6) and the relationship between hypothesis, theory and law (f:3) and to exemplify the scientific models used in different fields (f:6) and recognized the interdisciplinary structure of the nature of science (f:5), tentativeness of scientific knowledge (f:6) and the importance of creativity and imagination in the process of scientific research (f:8). In addition, the observations also revealed that the participants made explanations showing that they were able to understand the distinction between observation and inference (f:3) and create a new product with the help of knowledge and skills in different disciplines (f:2).

To illustrate, one of the focus students who had insufficient knowledge about the characteristics of scientific models at the beginning of the lesson said:

> *"Well, it seems to me that the discipline of history does not include any model … For example, you search the sources for history. You search for all the sources in the field where you will conduct your research … To me, the scientific model is something like the cult (Observation, 14th April 2015, S6)"*

At the end of the implementation, the change in the participant's knowledge and understanding regarding this subject was as follows:

> *If we give an example from maps, I think scientific model is like a small building block of science. It is comprehensive, free and memorable … For example, science, I mean the periodic table. It is a scientific model used in science. In geography and history: we have maps in history; for example, the maps of the Torunoğulları State in 1700s and 1800s … To me, it is not the real map but a similar one. A map cannot represent the reality. I mean it may be corrupted … (Interview, S6, p. 3).*

When the sub-categories of the categories of generalization and learning outcomes were examined in detail, it was seen that the indicators related to understanding the distinction between hypothesis, theory and law and explaining the relationship between these concepts were observed less frequently than the other learning outcomes. In addition, the interviews revealed that the deficiencies regarding this subject were not overcome at all.

One of the focus students reported in the reflective assessment form on 21st April 2015 that s/he learned this subject, saying "*I have learned the real relationship between law and theory. Previously, I thought that theory was based on untested information, but now I know that theory helps clarify the information in the related law and that it could exist before or after the law. Additionally, I've learned the real meaning of the concept of proof. I have also learned that endless experiments should be conducted to prove scientific knowledge (S2)*". The participant also stated during the interview that what s/he had learned was not permanent:

> *Law is general information, and theory is a sub-step of law. We explained theory based on law. If there were no law, then theory would be without any support. As for hypothesis, it comes first (Interview, S2, p.3).*

Another focus student made wrong or inefficient explanation regarding the relationship between hypothesis, theory and law, saying:

> *I think theory is something unproved. Hypothesis is the idea we put forward. Law is the proved method we use. Now, law is… These are all science, and all of them have influence on science. Hypothesis, I mean you put forward your proposition. Theory is something found between law and hypothesis, but it then becomes a law. I think law comes last (Interview, S1, p.3).*

Positive Factors Leading to Change

Figure 3 demonstrates the categories related to the positive factors which were revealed via the analysis of the interviews and the reflective assessment forms and which led to the change in the pre-service teachers' understanding of nature of science.

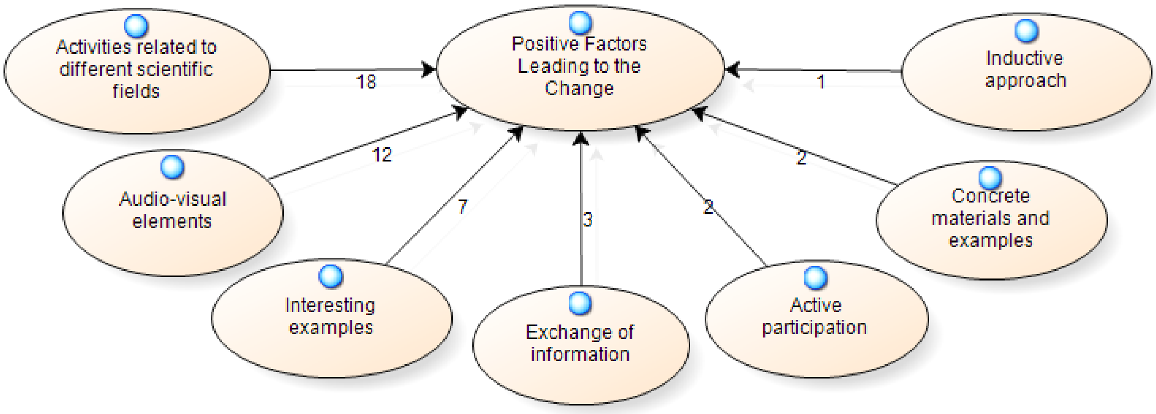

Figure 3. Positive factors leading to the change.

When Figure 3 is examined, it is seen that the audio-visual elements, interesting examples and activities which were related to different scientific fields and used in the implementation process contributed to the change in understanding of nature of science to a great extent. One of the focus students mentioned the activities related to different scientific fields, saying:

> *It was effective. I mean I had the chance to correct my previous wrong knowledge after we learned the subject in detail. I had given wrong answers to most of the matching exercises regarding hypothesis, theory and law. I learned the right ones, and I had the chance to overcome the deficiencies… For example, as far as remember, in the questionnaire, there was a question regarding the surfaces of the moon. While answering that question, I benefitted from different scientific fields like physics and geography (Interview, S5, p.4).*

Another student reported views about the contribution of audio-visual elements, saying:

> *I have always been interested in the change of the borders on the world map throughout history as well as in the visual reflection of this change because it is related to our own field (Reflective Assessment Form, 21st April 2015, ZE).*

Factors Making the Implementation Process Difficult

Figure 4 presents the categories related to the factors which were revealed via the analysis of the interviews and the reflective assessment forms and which made the implementation process difficult.

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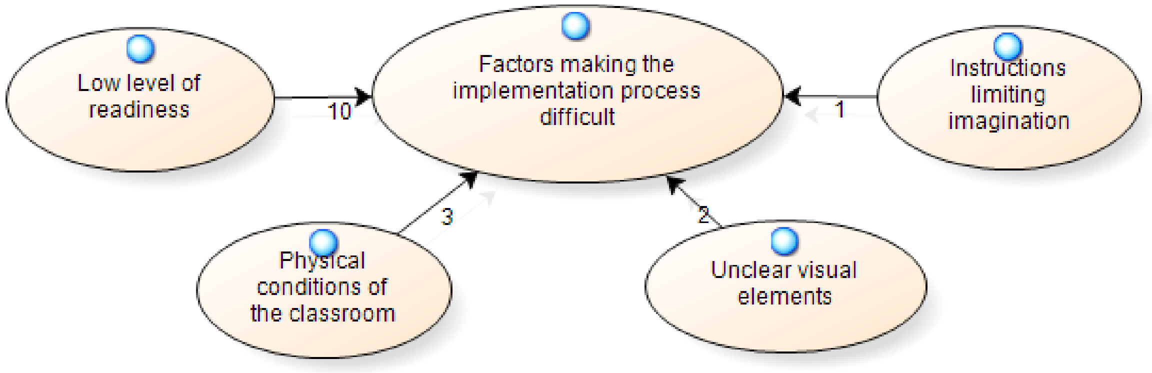

Figure 4. Factors making the implementation process difficult.

When Figure 4 is examined, it is seen that among the prominent factors making the implementation process difficult was the students' low level of readiness. In addition, three participants mentioned the physical conditions of the classroom environment, and two participants mentioned the unclear visual elements. One of the participants stated that the instructions used in the implementation of the activities restricted imagination. The focus students who pointed out that low level of readiness makes teaching difficult said:

> *For example, we were expected to fill out the given worksheets, and we had difficulty doing so. Initially, we tried to understand what it was. We didn't know anything about it. We only knew that there would be a training. We did not prepare for it in advance, and we did that training. While doing it, we had a little difficulty in this phase of thinking (Interview, S3, p.4).*

> *It was a complicated process. We experienced some difficulties because of our lack of readiness (Reflective Assessment Form, 14th April 2015, S1). For example, you showed those two photos. One of them was very close, and the other was very far, and it took a lot of time to understand it. We tried to understand it and compared it without background knowledge. What is all your knowledge about planets? (Interview, S1, p.4).*

Another student mentioned the characteristics of the physical environment, saying:

> *Because the lessons were carried out in an environment which was not appropriate at all, I had some difficulties like my illegible handwriting and the physical discomfort I felt (Reflective Assessment Form, 14th April 2015, SB).*

Discussion

The findings obtained in the research revealed that the nature-of-science curriculum based on the interdisciplinary approach, included introductory activities which aimed to attract attention to the subject and to examine the background knowledge and that a positive change in the students' understanding of nature of science was aimed with the help of presentation of information as well as with questions and related explanations, open-ended questions and activities making connections with different scientific fields. When the literature on interdisciplinary instruction principles is examined, it is seen that in the instruction process, it is important to examine background knowledge necessary for interdisciplinary connections and that it is essential to implement an inquiry-based instruction in which knowledge and skills based on different disciplines are integrated and in which students take an active part (Campbell & Henning, 2010; Erickson, 1995; Jacobs, 1989; Loepp, 1999; Mallanda, 2011; Mansilla & Duraisingh, 2007; Martinello, 2000). In addition, it is pointed out that students should make generalizations and use problem-solving and decision-making strategies based on the relationships between concepts (Meeth, 1978 cited in Garkovich, 1982; Erickson, 1995).

In line with the findings and the data reported in related literature, it could be stated that implementation appropriate to the features of an interdisciplinary approach was performed in the process of presenting and giving meaning to information; that the learning outcomes and generalizations of the curriculum were achieved; and that connections were established with different scientific fields within the curriculum design. In the research, it was found that among the learning outcomes and the generalizations, the indicators regarding the outcomes of "explaining the characteristics of scientists and scientific models and recognizing not only the factors influential on the nature of scientific observations but also the tentativeness of scientific knowledge" were observed more frequently, and in this respect, it was seen that different generalizations were made. On the other hand, it was revealed that the deficiencies regarding hypothesis, theory and law were not overcome at all. As examples of these deficiencies in learning, the pre-service teachers supported a hierarchical relationship between hypothesis, theory and law and maintained an understanding that proved theories turn into law.

The results obtained in other related studies demonstrate that activities carried out in relation to the subject failed to help understand the concepts of hypothesis, theory and law and the relationships between them (Küçük, 2008; Leblebicioğlu, Metin & Yardımcı, 2012) and that it was not easy to change the prevalent thought about the concepts (Abd-El-Khalick, 2005; Akerson & Hanuscin, 2007; Akerson, Morrison & McDuffie, 2006; Hanuscin, Akerson, & Phillipson-Mower, 2006). Leblebicioğlu et al. (2012) pointed out that this situation, which is also defined as misconception (McComas, 1998), has a relationship with lack of development of the philosophy of nature of science and that there is a need for long-term implementation for the development of philosophical understanding. In this respect, the failure to overcome the pre-service teachers' deficiencies regarding the subject of hypothesis, theory and law could be attributed to their lack of knowledge and understanding regarding the philosophy of science. When viewed from a more general perspective, it is thought that this situation is directly associated with the students' low level of readiness rather than just with the philosophy of science. The reason is that background knowledge about a subject is a powerful predictor of the level of learning (Champagne, Klopfer & Anderson, 1980; Taber, 2001). In contrast with the participants of many other studies, the pre-service teachers participating in this research were students in the department of Social Sciences Teaching. For this reason, compared to the pre-service teachers from science-related departments, pre-service teachers attending the department of Social Sciences Teaching might have lower levels of knowledge and skills regarding science and scientific research process. In addition, designing of the curriculum with an interdisciplinary approach requires integration of knowledge and skills regarding different fields of science. In studies establishing connection with interdisciplinary implementations (Barnes, 2011; Özer & Özkan, 2013; Wagner, Murphy, Holderegger, & Waits, 2012), it was reported that deficiencies in background knowledge are among the factors making the instruction process difficult. Moreover, in the present research, the fact that the pre-service teachers frequently mentioned their low levels of readiness as one factor making the instruction process difficult demonstrates that this situation, which was also perceived by the students, is among important issues which should be taken into account while teaching the nature of science.

More specifically, this situation could also be associated with the resistance to new concepts taught. The reason is that the process of conceptual change is known to require a multi-dimensional structure which involves an epistemological, ontological and socio-affective view point (Clough, 2006; Kyriakopoulou & Vosniadou, 2014; Lin et.al., 2016). It is seen that the factors influential on the process include background knowledge and such demographic characteristics as class grade, gender, reasoning and motivation as well as other different strategies regarding instruction process (Lin et.al., 2016). Therefore, it was found that in some short-term implementations expected to lead to a change, misconceptions show resistance to change and that permanent conceptual change cannot be achieved at all (Franke & Bogner, 2011; Champagne et.al., 1980; Özsevgeç, Çepni & Bayri, 207 cited in Gunstone, 1987; Leblebicioğlu, Metin & Yardımcı, 2012; Saka & Akdeniz, 2006). When the other findings were taken into consideration, it was revealed that among the most frequent positive factors leading to the change were audio-visual elements used in the process and that the pre-service teachers reported views about unclear visual elements which made the instruction process difficult. As an example for these views, it was seen that the participants mentioned photos which were not directly perceived as craters on the surface of the Moon but interpreted depending on personal experiences. The fact that audio-visual elements were among the positive elements which led to the change could be associated with the contribution of these elements to the process of perceiving, interpreting and giving meaning to the knowledge. The reason is that today, the effectiveness of

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the learning and teaching process is claimed to be increased with well-designed visual instruction materials, but in this process, it is pointed out that the ability to perceive and interpret visual messages should be taken into account (Yeh & Cheng, 2010). In this case, as mentioned in related literature, teaching of these elements could be said to contribute to the development of teaching of audio-visual elements, but it could be stated that some of the participants considered these elements to make the instruction process difficult since they did not acquire the ability to interpret visual elements at all. Among the other factors making the instruction process difficult, lack of good physical conditions indicates that physical conditions should be improved to conduct interactive group works. The basic reason for this situation is that Drama is the course most appropriate to conduct the implementation process. The reason is that the physical structure of the classroom appropriate to drama made difficult the process of filling out the worksheets and the assessment sheets within the scope of the activities. As mentioned by Hanuscin, Akerson and Phillipson-Mower (2006), in teacher education curricula, there are limited achievement opportunities for the development of understanding of nature of science. In order to solve this problem, it is pointed out that the related curricula should include different courses regarding the nature of science.

Conclusions

Consequently, in the present research, it was found that the nature-of-science curriculum, which was based on the interdisciplinary approach, caused a positive change in the pre-service teachers' understanding and knowledge regarding the nature of science. In this respect, it was seen that the deficiencies in learning such subjects found in the content of nature of science as "nature of scientific models, nature of observations and values guiding scientists in their work and social lives" were overcome to a great extent. In addition, it was seen that the participants' low levels of readiness made the implementation process difficult.

As a result, it was concluded that the curriculum which was developed with an interdisciplinary approach for the nature of science largely was in line with the requirements arising in the context of the current situation, provided to the developments of students' knowledge and understanding about nature of science and was implementable.

All these results obtained in the research were limited to the implementation of the nature-of-science curriculum developed with the interdisciplinary approach, in eight class hours in the department of Social Sciences Teaching. However, the results demonstrate that there is a need for structural reorganizations to develop understanding of nature of science with the help of long-term implementations in teacher education curricula. Within the scope of these reorganizations, the course of nature of science developed with the interdisciplinary approach could be suggested as a common course to be included in the teacher education curriculum in the second or third academic term. It is thought that the development of the curriculum of the course with an interdisciplinary approach could allow addressing different fields like social sciences teaching; that such a reorganization could help solve problems like resistance to new concepts and lack of background knowledge and skills; and that implementations lasting at least one academic term could lead to permanent changes in the understanding of nature of science.

Implications for future research are given below.

- Low levels of readiness of the pre-service teachers are among the factors that make the implementation process difficult. Therefore, it is suggested to conduct phenomenological researches on multi-dimensional and in-depth examinations of the factors affecting the level of readiness.
- In order to solve the problems encountered during the implementation process, it is thought that there is a need for action researches in order for pre-service teachers to eliminate the misconceptions about the concepts of hypothesis, theory and law, and to improve their skills to perceiving and interpreting visual messages.
- The curriculum implemented in this research can be evaluated at the different department and class levels in teacher education curricula and this evaluation can be supported by quantitative data.
- Since the curriculum development is a cyclical process, the curriculum based on the interdisciplinary approach can be implemented in the current context. With this implementation, development studies can be realized to make the curriculum more effective.

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