

Are We Prepared?: An Assessment of Preservice Science Teacher Educators' Beliefs About Nature of Science

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ABSTRACT: Given the important role of science teacher educators in developing science teachers' understandings of nature of science (NOS), this study explores 15 Turkish "prospective" science teacher educators' beliefs about NOS in the context of teacher education reform in Turkey. A reflection-oriented qualitative approach was adopted in the investigation. Data were collected through two sets of interviews with the participants and analyzed by means of cognitive maps. The analysis of data revealed that most of the participants of the study had inadequate conceptions regarding NOS. The majority of these inadequate conceptions were concentrated under two aspects of NOS: scientific method and the tentative NOS. The participants' inadequate conceptions appeared to be linked to a lack of prior reflection about NOS. The study has implications for the preservice preparation of science teacher educators, teacher education reform, and teacher thinking at both the practical and the policy levels. © 2006 Wiley Periodicals, Inc. *Sci Ed* 90:1113–1143, 2006

INTRODUCTION

Today, the need to promote a society of scientifically literate citizens is regarded as urgent in many countries and is accepted as one of the main goals of science education (Jenkins, 1997). It is generally accepted that achieving functional scientific literacy involves providing people with an understanding of science that they can use as they make decisions and engage

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in debate about scientific and technological issues outside formal education settings (Ryder, 2001). In this sense, educating for scientific literacy entails not only teaching science concepts and theories but also learning about the nature of these concepts and how they function in relation to other beliefs about the physical world (Eichinger, Abell, & Dagher, 1997). Therefore, nature of science (NOS) has been the focus of attention in science education circles as a primary component of scientific literacy (Bell & Lederman, 2003; Meichtry, 1999).

NOS has been defined in many ways in science education literature. The most cited definition of NOS is that by Lederman and Zeidler (1987) in which they refer to the values and beliefs inherent in scientific knowledge and its development. More specifically, McComas, Clough, and Almozroa (1998) define NOS as

... 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 endeavours. (p. 4)

Accordingly, science is more than just facts, laws, and theories. Although science does include facts, laws, and theories as a human activity, it is also composed of scientists doing investigations, the attitudes and beliefs these scientists hold, the processes they use, the community within science, and so on. Therefore, science education should also be more than just the teaching and learning of the structure of molecules or the surface temperature of the sun (Johnston, 2001). As the Royal Society (1985) proposes, learning and understanding science “includes not just the facts of science, but also the method and its limitations as well as an appreciation of the practical and social implications” (p. 2).

It should be noted that, in spite of the significant progress toward characterizing science, there is no single “nature of science” that fully describes all scientific knowledge and enterprises (Schwartz & Lederman, 2002) and that there is always likely to be an active debate at the philosophical level (McComas et al., 1998). On the other hand, these debates that philosophers and historians of science partake in regarding NOS are not necessarily useful to science education. Science education rather is interested in helping out individuals understand the basics of science in order to promote an effective literacy in science. At this level, significant academic consensus has been achieved on the aspects of NOS to be taught in school science (American Association for the Advancement of Science [AAAS], 1993; Driver, Leach, Millar, & Scott, 1996; McComas & Olson, 1998; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Smith, Lederman, Bell, McComas, & Clough, 1997). This consensual view describes science as a special way of knowing. It is accepted that there are methods and standards in science, but that they can vary from science to science and can, within science, be changed, and changed for the better (Chalmers, 1999). One of the central aspects of science is that all scientific knowledge, including “facts,” “theories,” and “laws,” is tentative. Reasons for this stem from several other aspects, such as (a) scientific knowledge has a basis in empirical evidence, (b) empirical evidence is collected and interpreted based on current scientific perspectives as well as personal subjectivity due to scientists’ values, knowledge, and prior experiences, (c) scientific knowledge is the product of human imagination and creativity, and (d) the direction and products of scientific investigations are influenced by the society and culture in which the science is conducted (Schwartz & Lederman, 2002, p. 207).

Clearly, science teachers who are knowledgeable about NOS play a central role in promoting functional scientific literacy in society. However, results of intensive research on both preservice and practicing teachers’ views of NOS revealed that science teachers, generally, do not possess adequate conceptions of NOS. For example, Abell and Smith (1994)

reported that 140 preservice teachers in their sample generally saw “science as a process of discovering what is out there, not as a human process of inventing explanations that work” (p. 484). In a similar fashion, Abd-El-Khalick and BouJaude’s (1997) study involving 20 in-service science teachers revealed that teachers’ views of NOS were fluid and lacked coherence. Such discouraging findings have been echoed by many studies, such as Aguirre, Haggerty, and Linder (1990), Cakir and Crawford (2004), Carey and Stauss (1970), King (1991), Lakin and Wellington (1994), Murcia and Schibeci (1999), Pomeroy (1993), Smith and Anderson (1999), and Tsai (2002) among many others (see Abd-El-Khalick & Lederman, 2000; Lederman, 1992 for an extended review of the literature on teachers’ and preservice teachers’ understandings of NOS). In light of research findings and assuming that teachers cannot possibly teach what they do not understand, researchers directed their attention to science teacher education programs and there has been intensive research on developing effective strategies and curricula to enhance teachers’ understandings of NOS (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000; Akindehin, 1988; Nott & Wellington, 1998).

Significance of the Study

What is missing in this literature and efforts, however, is the consideration given to the crucial role played by science teacher educators. Science teacher educators are also an influential component in science teacher education, as they have an influence on what is learned by future science teachers. It is clear that if science teachers are to improve their own conceptions about NOS, then it is surely the teacher educators’ role to facilitate effective curriculum planning and delivery, including the development of appropriate teaching strategies. Few would argue against the fact that science teacher educators’ beliefs play a pivotal role in their interpretation and conceptualization of the objectives of science education and science teacher education, and subsequent teaching behavior by acting as a constraint to the way they think about teaching and learning (Brickhouse, 1990; Bryan, 2003). However, despite their importance in educating knowledgeable and effective science teachers, our knowledge base about science teacher educators’ beliefs about NOS is limited (Richardson, 1996).

It is important to note that there have been some institutional attempts to establish professional standards for science teacher educators in recent years. For example, in 1997, the Association of the Education of Teachers in Science (AETS) Ad Hoc Committee on Science Teacher Educator Standards developed standards for those involved in the preparation of science teachers. These standards are meant for individuals beginning a career as a science teacher educator and were developed to clearly articulate and define a framework for the skills, knowledge, and experiences necessary for successful science teacher educators. Having a functional understanding of NOS was highlighted among the knowledge essential for the successful science teacher educator.

Standard 1.d. The beginning science teacher educator should possess levels of understanding of the philosophy, sociology, and history of science exceeding that specified in the reform documents. (p. 236)

It is noted that a science teacher educator should not only possess a particular coherent perspective concerning NOS but also be aware of alternative viewpoints held by other respected professionals.

Although such standards do help to identify the essential qualifications for the science teacher educator, the question “what conceptions do science teacher educators possess regarding NOS?” still remains. It seems that all the research conducted on students’ and teachers’ conceptions of NOS and all suggested program designs aiming to improve preservice or in-service teachers’ understandings of science have been simply guided by the

assumption that science teacher educators, who, naturally, are responsible for implementing these programs, have an adequate understanding of NOS. For example, we can clearly see this assumption when Bentley and Fleury (1998) wrote:

For science teacher educators, the instructional problem is how to help their students—present and future teachers—understand post-positivist perspectives of science and what they mean for curriculum and instruction. No teacher educator can transfer his/her own knowledge about science to the student, but he or she can provide opportunities for conceptual change and model appropriate instruction. (p. 278)

However, this assumption is yet to be tested. In this sense, assessing the beliefs of science teacher educators with regard to NOS is crucial for the success of the attempts to improve preservice and in-service teachers' understandings of NOS.

Toward this end, this study aims to contribute to the knowledge base about the beliefs of science teacher educators by providing important information about the beliefs regarding NOS of a group of "prospective" science teacher educators (PSTE). Furthermore, it does this in the context of a teacher education reform in Turkey, which raises the importance of the study not only from the Turkish point of view but also for other countries that aim to reform their teacher education systems through similar approaches.

The Context of the Study

The Profile of Science Education in Turkey. Today, calls for reform in science education in Turkey are as loud and clear as elsewhere in the developed world. Like many governments around the world, the Turkish government is aware of the importance of preparing its citizens for the challenges of the new century, and perceives the promotion of scientific literacy in society as an important goal of science education (Ministry of National Education [MNE], see; www.meb.gov.tr). However, science education, in particular, is still far from the desired level (Ayas, Cepni, & Akdeniz, 1993). Science education curriculum has been criticized on the basis that it is content based (Turkmen & Bonstetter, 1998) and gives less priority to student-centered activities (Cakici, 2001; Turkmen & Bonstetter, 1998). Furthermore, Cakici (2001) argues that the Turkish national curriculum includes far too many topics and does not allow flexibility for teachers to select the content. The role of the teacher is to provide predetermined information in the light of the main aims of the curriculum (Cakici, 2001). This situation requires students to absorb a static body of scientific knowledge and also encourages rote learning rather than meaningful learning (Ekiz, 2001).

Especially in the last two decades, science education in Turkey has been greatly influenced by entrance examinations at different educational levels. The most influential examination in a typical Turkish student's life is the university entrance examination, which is called OSS. Although some alterations have been made recently, traditionally, the university entrance examination assesses the content knowledge of students in a variety of subjects such as biology, chemistry, Turkish, and maths. This has affected teaching and learning negatively in the nation's schools. Getting a high score in the university examination has required the mastering and memorizing of content by the students. Teaching has become a transmission of content knowledge and a successful and effective teacher is perceived as one whose students perform well in the exam (Cimer, 2004). Practical work, field trips, and social facets of schooling have been neglected (Cimer, 2004).

This situation, inevitably, has affected the profile of science education as well. Arguably, it has led many students and science teachers to associate the study of science subjects at school with memorization of the vocabulary of science, with little emphasis on understanding underlying scientific processes. Many students appeared to do well in the exam, yet without

showing motivation for or demonstrating an understanding of science. Few would argue against the fact that this memorization of the content of science has also led these students to associate science with a set of "truths" (Tobin & McRobbie, 1997).

The picture is not different from the teachers' perspective. Teaching in schools is teacher centered (Ersoy, 1995), which relies on strategies that can be best described as information transmission ultimately derived from behaviorist theories (Cakici, 2001). As Cakici concludes:

The objective of classroom teaching and learning in science education in Turkey, then, is to provide the student with as much scientific information as possible by emphasizing the teaching of basic facts and definitions, and then to measure the quantities of scientifically acceptable information retained by children. (p. 9)

Reform Efforts. The Turkish government has implemented many reforms in the last decade in order to improve the quality and effectiveness of the national education system (Gursimsek, Kaptan, & Erkan, 1997). Within this reform movement, teacher education has attracted special attention due to its failure to educate quality teachers.

Like in many countries, teacher education in Turkey moved from teacher colleges to universities in the early 1980s (Kucukahmet, 1986). The reason for this shift was to attract quality students to the teaching profession and provide a strong research and theoretical base for teacher education (Wideen & Grimmet, 1997). This understanding led many governments, including the Turkish government, to transfer the duty of teacher education to universities, which were considered to be the source and the producers of academic knowledge.

Although this movement was intended to improve the quality and effectiveness of the teacher education system, it failed to solve some crucial problems and also brought some serious new problems along with it in Turkey. As a result of this unification and increase in the number of admissions, faculties of education began to suffer from a lack of physical facilities, equipment, faculty, etc. (Altan, 1998). Among these, the lack of qualified teaching staff in teacher training institutions was particularly critical and to fill the faculty gap, many faculty members from faculties of science and literature transferred to faculties of education (Altan, 1998).

This situation created a big problem in that the faculty members who transferred from faculties of science and literature were expert in their subject areas but ineffective in their understanding of teaching as they were not trained in methodology or pedagogy. The majority of these faculty members did not produce research or contribute to debates about education; instead they preferred to carry out research in their subject areas, and as a result, teacher education as a subject was neglected (Higher Education Council [HEC], 1998). Furthermore, these academics in faculties of education perceived scientific enterprise from a positivistic standpoint (Cakiroglu & Cakiroglu, 2003) and influenced their students in this direction. A study by Yalvac and Crawford (2002) seems to support this argument. In a study involving 25 preservice science teachers, Yalvac and Crawford found some serious misunderstandings among preservice teachers concerning scientific method, scientific laws, and the subjective NOS, and concluded that the participant student teachers viewed science from a logical positivist point of view.

The crisis in the teacher education system coupled with its undesirable effects on the quality and effectiveness of education, in general, led the HEC and the MNE to review and consider appropriate ways to restructure teacher education. A new regulation was developed and introduced in 1998 (Restructuring the Teacher Education Programs in Education Faculties). Within this reform movement, improving the quality of faculty in teacher education programs is positioned at the top of the reform agenda.

Toward this end, with the new regulation, academics in faculties of education with a pure subject background (such as biology or chemistry) and interest were transferred to faculties of science and literature. In order to meet the shortage of staff that emerged as a result of this transfer, the MNE and the HEC allocated approximately 750 overseas doctoral scholarships in 1997/1998 (HEC, 1999). Of these scholarships, 116 were allocated to science teacher education. Candidates (with a variety of backgrounds such as agricultural engineering, biology, education, etc.) for these overseas scholarships sat an examination called the "Examination for Postgraduate Studies Abroad" (YLS). Successful candidates were sent to different western countries (England, the United States, and France) to become qualified in teacher education after completing a language preparatory course. The intention is, in the long term, when these students return to their home universities they will change the culture of the faculties of education through the experiences they have gained by studying abroad and will make an important contribution to the educational studies, policy, and practice in education in Turkey.

To this end, this study focuses on a group of prospective science teacher educators (PSTE) who, at the time of the study, were studying abroad as a part of the Turkish government's strategy to improve the quality of teacher education and assesses the beliefs of these teacher educators regarding NOS.

METHODOLOGY

The Participants

At the early stages of the study, a search was conducted to identify potential participants who were involved in the project. As a result of this search, 30 individuals in England and in the United States were identified. These potential participants were contacted through e-mails. The e-mail messages sent to them included a brief description of the study and an invitation for them to participate. Fifteen of these 30 individuals responded positively and participated in the study. The ages of the participants varied between 25 and 30 years. All of the participants were conducting their doctorate level studies in science education in England or in the United States. In order to provide anonymity, codes were used to represent them in this study (e.g., TE1; "TE1" stands for *Teacher Educator One*). The backgrounds of the 15 participants were quite varied. Table 1 presents the information about the participants' field of study, undergraduate major (BS) and Master of Science (MS) degrees, teaching experiences, gender, and the country in which they were conducting their studies at the time of this research was being undertaken.

The group consisted of nine males and six females. The participants varied quite markedly regarding their first degrees. All of the participants got their first degrees from universities in Turkey. The reader is reminded that the participants' fields of study in which they would be teacher educators were decided according to their first degrees. Five participants had first degrees from various engineering departments. TE1, TE12, and TE13 had majored in agricultural engineering. TE1 and TE13 also had MS degrees and research experience (both for 4 years) in the same field. They all were doing their doctorates in biology education and they were to be teacher educators in this field. TE4 had a chemical engineering degree and was studying chemistry education to be a teacher educator in this field. TE6's degree was in mechanical engineering and he was studying physics education. TE2, TE5, and TE7 graduated from science faculties. TE2 and TE7 majored in physics whereas TE5 had BS and MS degrees in biology; they were studying physics education and biology education, respectively. The remaining seven participants graduated from education faculties. TE3 and TE14 had baccalaureate degrees in chemistry, TE8 and TE11 in biology, TE9 and TE10 in physics, and TE15 in primary education. TE11 also had an MS degree in biology education.

TABLE 1
The Participants' Background Information

	Field of Study	Background	Teaching Experience	Gender	Country
TE1	Biology education	Agricultural engineering (BS + MS)	In higher education (4 years)	Male	England
TE2	Physics education	Physics (BS)	In secondary (3 years)	Male	USA
TE3	Chemistry education	Chemistry education (BS)	In primary and secondary (4 years)	Female	USA
TE4	Chemistry education	Chemical engineering (BS)	No	Male	England
TE5	Biology education	Biology (BS + MS)	No	Female	USA
TE6	Physics education	Mechanical engineering (BS)	No	Male	England
TE7	Physics education	Physics (BS)	No	Male	England
TE8	Biology education	Biology education (BS)	In secondary (1 year)	Male	USA
TE9	Physics education	Physics education (BS)	In primary and secondary (4 years)	Female	USA
TE10	Physics education	Physics education (BS)	In primary, secondary (2 years) and higher education (3 years)	Male	England
TE11	Biology education	Biology education (BS + MS)	In secondary (1 year)	Female	USA
TE12	Biology education	Agricultural engineering (BS)	No	Male	England
TE13	Biology education	Agricultural engineering (BS + MS)	In higher education (4 years)	Female	England
TE14	Chemistry education	Chemistry education (BS)	In higher education (2 years)	Female	England
TE15	Biology education	Primary education (BS)	In higher education (2 years)	Male	England

Five participants explained that they did not have any teaching experience. Four participants had some teaching experience as teaching assistants in higher education institutions. Among them TE1 and TE13 had taught in agricultural engineering departments, TE14 and TE15 had some teaching experience in higher education departments (in chemistry education and biology education, respectively). The remaining six participants, on the other hand, had science teaching experiences in primary and/or secondary schools.

Nine of the 15 participants were conducting their doctorate level studies in England whereas six of them were in the United States. The doctoral programs that the participants from England attended were 3-year programs where, generally speaking, doctoral students follow four or five modules (such as research methods, curriculum and planning, comparative teacher education) on their first year and work on their doctoral research projects thereafter. In the United States, on the other hand, the length of the doctoral programs was 4 years. Doctoral students in science education usually take various courses in the first 2 years of the program (e.g., teaching and learning in science education, educational research), then continue on their research projects depending on their success in comprehensive exams. All the participants in the study explained that although courses on the history and philosophy of science exist in their programs, these courses are selective, not a core part of the program.

Data Collection

The data collection process involved two interviews with each of the participants. The first set of interviews took place between February and March 2003 and the second interviews were conducted between June and August 2003. Interviews were carried out in Turkish as both the researcher and the participants were native speakers. In this way, the participants were able to express their beliefs comfortably without any language barrier. The data were also analyzed in Turkish so as not to lose the actual meaning of the participants' explanations in the translation process. The parts to be quoted in the final report of the study were translated into English at the end of the data analysis process. The quality and meaningfulness of these translations were checked with the help of a native English speaker.

All the interviews with the participants who were conducting their studies in England involved face-to-face interviews. All face-to-face interviews were audio-taped for analysis. The interviews with the participants in the United States were conducted through the Internet using MSN Messenger software. Recent developments have presented opportunities for computer users to simulate face-to-face interviews by communicating synchronously by talking and seeing each other. This is achieved through the use of web cameras and a microphone. An influential factor in making the decision to use synchronous web cameras to conduct the interviews with the participants in the United States was the fact that all the participants had access to Internet-connected computers with the necessary hardware (microphone and web camera). The interviews were, in one sense, very similar to face-to-face interviews as even facial expressions were clearly visible. All the interviews were saved on to the hard disc drive of the researcher's computer for analysis.

The first interviews started with questions about the participants' personal details and backgrounds. The participants' conceptions about science were assessed through the questions of the VNOS-C (Views on Nature of Science Questionnaire, Form C) developed by Abd-El-Khalick (1998). The original form of the VNOS questionnaire was developed by Lederman and O'Malley (1990) and consisted of seven open-ended questions. It was used in conjunction with follow-up individual interviews to assess high school students' views of the tentative nature of science (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2001). In 1998, the questionnaire was modified twice and the final form (Form C) based on 10 questions was developed by Abd-El-Khalick et al. (2001). Although the original

questionnaire was developed as a paper-and-pencil instrument, the questions were also appropriate for use in interviews since they were open-ended. Through these questions, the participants' views about several aspects of NOS were assessed. These aspects included, for example, the empirical and tentative nature of scientific knowledge, the nature of scientific method and scientific theories, the creative and imaginative nature of science, the subjective nature of scientific knowledge, and social and cultural influences on scientific knowledge. The significance of these aspects is that they, when considered together, cover much of what is central to the description of what NOS is and, therefore, helped reveal a complete picture of the participants' beliefs about NOS.

Data Analysis Procedure

The procedure for analysis of the data obtained in the first interviews was quite similar to that suggested by Hewson and Hewson (1989), except for the generation of cognitive maps. The first step of the analysis involved the *coding* of the data. First, the transcriptions were read. In coding, each question was assigned with a number. Then, each sentence implying a unit of information in the participant's answer was also given a number. The following is an example of such coding taken from TE1's transcription.

Question (21), Interviewer: After scientists have developed a scientific theory, for example atomic theory or the theory of evolution, does the theory ever change?

TE1: 1 (If we still call it a "theory," yes, I believe that it changes.) 2 (If a theory has not been not accepted by everyone, what I mean by everyone is 'scientists' or the "scientific community"), 3 (because it has not been proven) 4 (due to insufficient technology or lack of knowledge in that field,) then it changes. 5 (For example, we did not know the structure of the DNA until Watson and Crick developed that model in 1956, with that model they explained that genes located on the DNA are the key for our lives and "the information" is transferred to next generation through the DNA.) 6 (Today technology is so developed that we are able to change the locations of genes on the DNA.) 7 (We do not call it "the theory of DNA" or "the theory of Watson-Crick," I mean it is apparently proven.) 8 (There were different theories regarding this issue until 1956, but now . . .)

The second step of the data analysis involved *theme (or category) generation* (Hewson & Hewson, 1989). Here, the participants' statements regarding NOS aspects (or themes) were grouped together. For example, a participant's statements that informed his/her understanding of the tentative NOS were grouped together. At the end of this process, each participant's statements were grouped under 9 themes (or aspects of NOS) regarding NOS, which were: (1) description of science, (2) the empirical NOS, (3) scientific method, (4) the tentative NOS, (5) the nature of scientific theories and laws, (6) inference and theoretical entities in science, (7) the subjective and theory-laden NOS, (8) social and cultural embeddedness of science, and (9) imagination and creativity in science.

The themes were not independent of one another as they represent components of a conception of NOS. Therefore, some of the statements were placed within more than one theme as they applied to all these themes. Furthermore, some of the themes were broad, for that reason, they consisted of several subthemes. For example, four subthemes were detected under the theme *the nature of scientific theories and laws*, which were: (1) theories: well-supported explanations vs. guesses, (2) theory change, (3) the relationship between theories and laws, and (4) the status of laws.

This theme-generation process helped the researcher to check the consistency, or lack thereof, between the participants' statements regarding an aspect of NOS that were made in

TABLE 2
An Example of *Statement Generation Process* (Taken from the Analysis of TE1's First Interview)

...

Science represents systematically collected knowledge (7.1, 2)

Science relies on evidence (11.4)

A discipline should follow the scientific method to be called 'scientific' (11.2, 3)

Scientific knowledge is clear, commonly accepted, and collected without any interpretation (11.5; 12, 3, 4; 18)

Scientists use their imagination in developing theories (34)

Scientists should not use their imagination unwisely in attempting to explain unscientific phenomena (34.6, 7)

One of the main aspects of the scientific knowledge is that it is repeatable and clear (18)

Scientists should not make claims without direct evidence (31.1)

Scientific method is the same in all scientific disciplines (13; 14; 15)

Scientific method: theory—systematic data collection by experiment and observation—evidence—conclusion (13.2, 3)

Theories are unproven proposals (20; 21)

Due to insufficient technology and lack of knowledge (21.4)

Theories have not been accepted by all scientists (20.4; 21.2)

Theories change (21)

Theories become laws if they are proven (22; 23)

Example: The DNA model (21)

Laws do not change (22.3)

...

response to different questions. Any inconsistency identified as a result of this analysis was noted and was followed up with the participant in the second interview for clarification.

The third step was *statement generation*. This involved summarizing the participant's detailed explanations in a single sentence or phrasal statements. An example of this process is shown in Table 2.

The last step of the analysis was *the generation of cognitive maps* regarding NOS for each participant. These cognitive maps were generated by employing a technique that is analogous to that developed and used by Novak and Gowin (1984) for concept maps. Concept maps are intended to represent meaningful relationships between concepts in the form of propositions (Novak & Gowin, 1984).

The difference between a cognitive map and a concept map is that a cognitive map is drawn from a particular piece of text, such as an interview transcription, and the reader analyzing the text is interrogating, rather than the person (Miles & Huberman, 1994). Furthermore, cognitive maps relate, in a partially hierarchical manner, units of information in a broader sense than the concepts used in conceptual maps (Mellado, 1997). In this sense, the cognitive maps generated and presented in this study display an overall picture of the participants' beliefs concerning NOS.

The sentences and phrases (units of information) obtained in the third step (statement generation) were used to construct cognitive maps. The construction of cognitive maps involved careful analysis of these units of information, classification of these units into categories, and identifying the relationship between them. After being confident about these relationships, the concepts and the relationships between them were represented graphically in the form of a cognitive map. Figure 1 shows TE1's cognitive map on science constructed as a result of this data analysis procedure. These cognitive maps were constructed for all the participants.

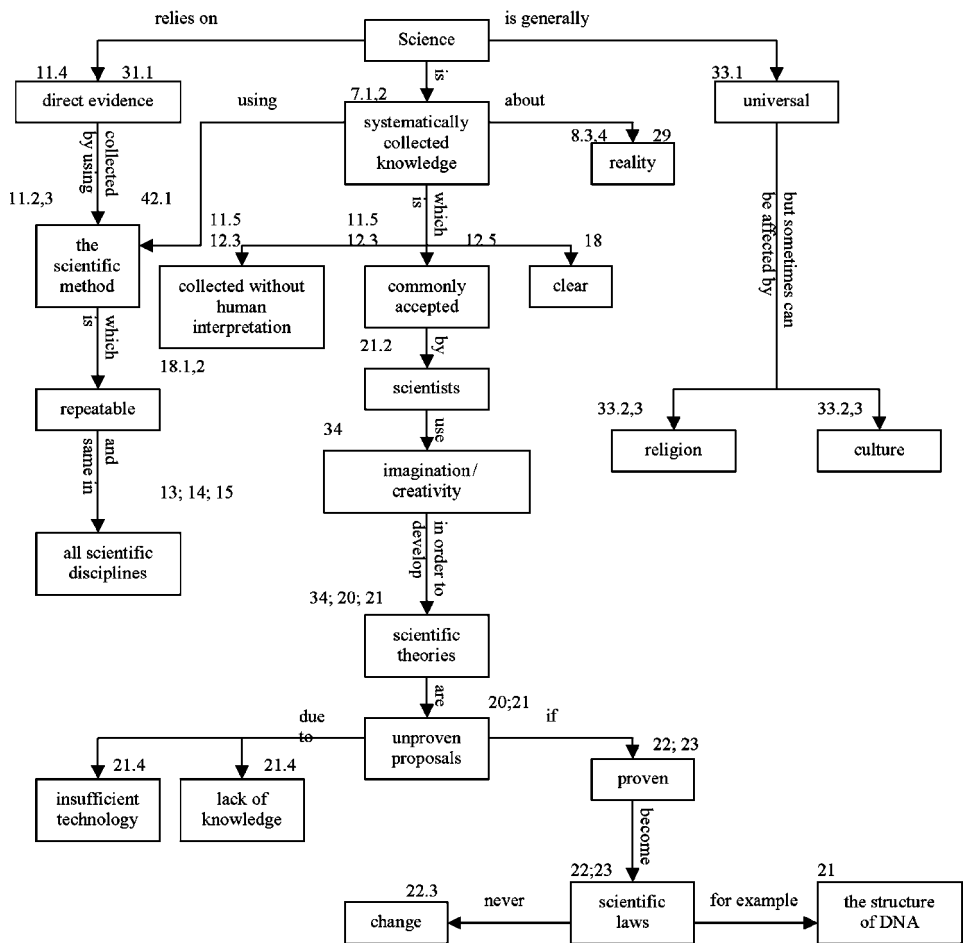


Figure 1. TE1's cognitive map on science generated on the basis of the first interview.

These generated cognitive maps were used as a research strategy in this study. Arguably, beliefs about science and its nature represent one of the most highly complex belief systems and as such it is not easy for individuals to express their beliefs completely and accurately without some form of careful reflection. In this sense, the cognitive maps that were constructed based on the analysis of the first interviews were sent to the participants to encourage the participants to reflect upon their beliefs as well as ensuring the authenticity and validity of the maps. The idea was that being confronted by a graphical representation of their beliefs generated by an outsider would lead the participants to explore their beliefs through reflection. Therefore, upon completion of the analysis of the first interviews, the transcriptions and the cognitive maps constructed concerning NOS were sent to the participants by e-mail at least 2 weeks before the second interviews.

As in the first interviews, the second interviews with the participants in England were carried out face-to-face whereas those in the United States were conducted synchronously using MSN Messenger software over the Internet. The difference between the first and the second interviews was that the latter were clinical in nature in that the questions for each participant in the second interview were developed during the analysis of the first interviews and so were different for each individual participant.

The second interviews started with conversations about the cognitive maps. The participants were mainly asked whether they felt that the cognitive maps reflected their beliefs about science and its nature. These conversations led to further discussions and questions about contradictions and inconsistencies in their beliefs detected in the analysis of the first interviews and illustrated in their cognitive maps. In this process, the participants were given an opportunity to make changes to their cognitive maps and to provide the reasons for that change. To give one instance, TE1's cognitive map for science that was modified in the light of his explanations in the second interview is illustrated in Figure 2. The shaded areas in the figure show the modifications that were made after the second interview with TE1 in accordance with his explanations.

At this point, it is important to note that the cognitive maps presented in this paper were constructed in the light of the analysis of two interviews with each individual. The codes located above each box on the cognitive maps show from which part(s) of the interview that specific information is obtained. In order to avoid any confusion, any information unit obtained from the second interviews is coded with the "*" sign whereas the codes showing the units of information obtained from the first interviews do not carry any symbols. For example, 8.2,3* indicates that this information was obtained from the second and third

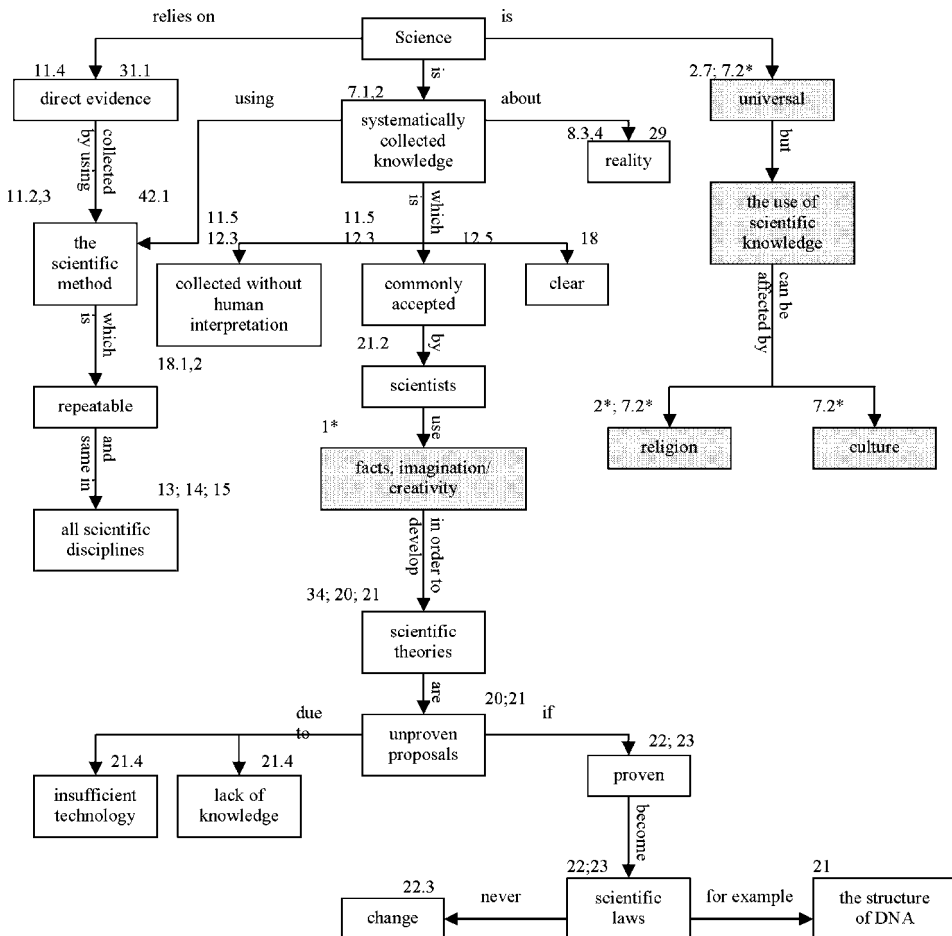


Figure 2. TE1's cognitive map on science after the second interview.

sentences of the 8th question asked in the second interview whereas 27.1 indicates that the information in this box was obtained from the first sentence of the 27th question asked in the first interview.

RESULTS

The interviews revealed that only 2 of the 15 participants (TE8 and TE11) had attended a course on the history and philosophy of science (HPS). However, including these two, five participants (TE6, TE7, TE8, TE10, and TE11) indicated that they were interested in the philosophy of science or social science and had engaged in independent reading in these issues. Arguably, because of this lack of previous interest and reflection, the majority of the participants suffered from various inadequate conceptions regarding NOS, similar to those revealed by research on science teachers' and students' understandings of NOS.

The findings concerning the participants' beliefs about NOS are summarized in Table 3. This table presents the participants' conceptions about different aspects of science in relation to each other. It also allows making comparisons across the individuals regarding their understandings. In the left-hand column of the table are the themes and statements that have been frequently cited by recent science education reform documents (e.g., AAAS, 1993) and researchers in various studies (e.g., Abd-El-Khalick et al., 2001; McComas & Olson, 1998; Osborne et al., 2003). These themes and statements are considered as adequate statements that reflect and highlight at least some aspects of science. The participants are placed at the top row.

The "•" symbol in each participant's cell corresponding to each theme or statement shows the participant's agreement with the theme or statement in consideration as revealed by the analysis of the interviews. If there is no symbol then it indicates the disagreement of the participant with that statement. The last column on the right-hand side gives the total number and percentage of the participants agreeing with the theme or statement. By looking at these percentages, one can identify the problematic areas within the group. The last row at the bottom of the table, on the other hand, reveals the total individual scores. The reader can see each individual's rate and percentage of agreement with all the themes and statements presented.

Group's Performance

By looking at the overall group percentages on the right-hand-side column of the table, one can see that the most problematic aspects of NOS within the group were *scientific method* and *the tentative NOS*. Total percentages of the participants agreed with the related themes and statements did not exceed 50% on any of these aspects of science.

As the table reveals, only 20% of the participants (3) agreed with the statement that "there is not a single scientific method." These participants believed that scientists employ different methodologies and logic depending on the phenomena being studied, but pointed out that there are some general rules and regulations to be observed in all scientific investigations. For example, one of these participants (TE7) explained:

... I know that many people believe in the existence of a universal method in science. Well, I don't think such a thing exists. I think it is against the nature of science. Scientists should seek for the most appropriate way or method for their investigations, and I believe that do it. (TE7.2: 6.2,3,4,5)

He believed that the most important step in a scientific investigation in order to establish its methodological and analytical validity is the careful reporting to the scientific community.

TABLE 3 Overall Analysis of the Participants' Beliefs About NOS

NOS Aspect	Naïve					Eclectic					Informed					Overall Group Performance	
	TE1	TE15	TE6	TE3	TE4	TE2	TE5	TE14	TE9	TE12	TE7	TE11	TE10	TE8			
Description of science																	
Science as a way of knowing				•	•	•	•	•	•	•	•	•	•	•	•	•	8/15 (53%)
The empirical NOS																	
Does not rely solely on direct evidence				•	•	•	•	•	•	•	•	•	•	•	•	•	7/15 (46%)
Supportive role of evidence				•	•	•	•	•	•	•	•	•	•	•	•	•	8/15 (53%)
Scientific method																	
No single scientific method				•	•	•	•	•	•	•	•	•	•	•	•	•	3/15 (20%)
Is not a stepwise procedure				•	•	•	•	•	•	•	•	•	•	•	•	•	7/15 (46%)
The tentative NOS																	
Scientific knowledge is tentative					•	•	•	•	•	•	•	•	•	•	•	•	6/15 (40%)
Relative to social context					•	•	•	•	•	•	•	•	•	•	•	•	3/15 (20%)
Theories and laws																	
Theories are well sustained				•	•	•	•	•	•	•	•	•	•	•	•	•	10/15 (66%)
Theories may change	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
Due to new evidence	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
New ways of looking at existing evidence	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	8/15 (53%)
Laws may change																	
No hierarchical relationship				•	•	•	•	•	•	•	•	•	•	•	•	•	6/15 (40%)
Inference and theoretical entities																	
Inferential nature of some theories				•	•	•	•	•	•	•	•	•	•	•	•	•	8/15 (53%)
The subjective NOS																	
Observations are theory-laden				•	•	•	•	•	•	•	•	•	•	•	•	•	9/15 (60%)
Are affected by values and beliefs				•	•	•	•	•	•	•	•	•	•	•	•	•	9/15 (60%)
Differences in data interpretation				•	•	•	•	•	•	•	•	•	•	•	•	•	11/15 (73%)
Social and cultural influences																	
Science as a product of culture				•	•	•	•	•	•	•	•	•	•	•	•	•	8/15 (53%)
Society influences science				•	•	•	•	•	•	•	•	•	•	•	•	•	13/15 (86%)
Science as a culture within itself				•	•	•	•	•	•	•	•	•	•	•	•	•	3/15 (20%)
Creativity and imagination in science																	
Involves imagination and creativity	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	15/15 (100%)
At all stages																	
Overall Individual performances	3/22 (14%)	4/22 (18%)	7/22 (32%)	8/22 (36%)	9/22 (41%)	11/22 (50%)	11/22 (50%)	12/22 (55%)	13/22 (59%)	13/22 (59%)	18/22 (82%)	20/22 (90%)	21/22 (95%)	22/22 (100%)	21/22 (95%)	22/22 (100%)	180/330 (55%)

... One of the important aspects of scientific investigation is that other scientists should be able to understand the study you have done and see the results you have found. For this reason, reporting is very important ... (TE7.2: 7.1.2)

The majority of the participants (12), on the other hand, believed that there exists a universal scientific method. These participants claimed that the existence of this unique method is one of the most important differences that distinguish science from other disciplines. Furthermore, more than half of the participants (54%) claimed that this method is a stepwise procedure.

As a matter of fact, when we talk about science we mean a particular and universal method ... I mean scientists put forward a hypothesis first, then, design experiments and observations in order to prove it ... (TE15.1: 23.2)

... You have a hypothesis, conduct experiments and observations to show if it is true or false. (TE5.1: 14.2)

A discipline should be given to all scientists to follow the steps of scientific inquiry. Look at us; although we are in the social sciences even we are given that discipline here, because it is necessary. (TE1.1: 15.1,2)

This finding has been commonly reported in many studies of students' and teachers' beliefs (e.g., Akerson et al., 2000; Lakin & Wellington, 1994) and attributed as one of the most widely held misconceptions about science (Abd-El-Khalick et al., 2001; McComas, 1998).

Similarly, the majority of the participants (9 of 15; 60%) failed to recognize the tentative nature of scientific knowledge regardless of its nature and status. It seemed that the most important factor contributing to these participants' absolutist views regarding scientific knowledge was their beliefs regarding the relationship between scientific theories and scientific laws and the nature and status of scientific laws. The majority (10 of 15; 67%) believed that there is a hierarchical relationship between scientific theories and scientific laws; that is, scientific theories become scientific laws when proven. Furthermore, although all the participants accepted the tentative nature of scientific theories, many of them (9 of 15; 60%) perceived scientific laws as the final form of scientific knowledge representing truth and, therefore, not subject to change.

Laws are explanations about general phenomena and processes which were proposed as theories then proven and accepted. (TE1.1: 23.1)

Of course there is a relationship, you propose a theory, prove it and it becomes a scientific law. I mean, there is a hierarchical relationship between the two. (TE10.1: 26.1,2)

Laws do not change, because we call them "laws". (TE6.1: 29)

Laws are in a position that cannot be falsified by anything ... (TE14.1: 26.1)

There is no doubt that there is a hierarchical relationship between the two. In one sense scientific laws depend on theories. If you prove a theory then it becomes a scientific law; if you cannot then it remains as a theory. (TE12.1: 28.1,2,3)

Again, the research literature on teachers' understandings of NOS indicates that this misconception is not uncommon among teachers. For example, Murcia and Schibeci (1999) reported a lack of awareness of the tentative nature of scientific knowledge among 73 preservice primary science teachers in their sample. Only 22% respondents in their sample addressed the tentative nature of research findings with varying degrees of complexity. In a similar fashion, Mueller and Wavering (1999) found that science interns in their sample did not have well-defined concepts of facts, laws, and theories. They believed that laws are formed from facts and that they are not going to change.

Analysis of the interviews revealed one interesting finding that some of the participants (TE1, TE5, TE6, TE13, and TE15) gave different values to different theories. For example, TE15 did not hide his skepticism about the validity of the theories on the extinction of dinosaurs.

... I think none of them are logical. Because many changes have taken place in the world even within the last two thousand years, 65 million years [emphasises], it is a very long time ago. It is difficult to make an estimation about things that happened that long ago ... How can they [scientists] be sure about it? It is not 64, not 63 but 65! Even one million years is an unbelievable time period. (TE15.1: 48.2,3,4,7,8,9)

His ideas about the theory of evolution were almost the same. However, he thought highly of atomic theory. According to him, we use atomic theory because it is a reliable theory and it can be proven in the future with the development of more sophisticated technologies. In the light of these explanations, in the follow-up interview, he was asked which theory is more true and believable: atomic theory or the theory of evolution.

TE15: Of course atomic theory.

Interviewer: Why?

TE15: Because everyone accepts atomic theory. It is clearer. As I mentioned before the theory of evolution is about something that happened a long time ago. I do not believe many things on this issue, even the fossil evidence. I mean, they are making estimations about a creature, but [pause] was it an animal or not? Because, it is impossible to prove, it happened a long time ago. In fact, I sometimes do not believe some events reported as historical facts.

Others (TE1, TE5, TE6, and TE13) expressed similar views about the status of different theories. They thought that it is impossible to prove the theory of evolution since it is about the past while atomic theory or similar theories are likely to be proven in the future in the light of developing technology.

Apart from these two aspects of NOS, the group's overall percentages regarding some other statements assessed under the other aspects of NOS were also remarkably low. For example, only 20% of the participants acknowledged the scientific community as a culture that establishing rules of practice and validity of claims and evidence. This finding closely resembles Abell and Smith's (1994) finding in which they reported that no one among their sample of 140 preservice elementary teachers mentioned the scientific community or the role it plays.

Similarly, while all participants agreed that creativity and imagination permeates science, most of them (80%) believed that this involvement is limited to certain stages in scientific investigation. Remarkably, a crucial relationship was detected between conceptions regarding scientific method and creativity and imagination in science. As seen in the table, the participants claiming limited involvement of imagination and creativity in science were those who defended the existence of a single and universal scientific method in science. Only three participants (20%) believed that creativity permeates the scientific process throughout; it is required in the development of the earliest conceptions of a research question, in designing and running an investigation, and in the interpretation of the results of the investigation. They viewed creativity in science both in terms of resourcefulness in carrying out experiments and in inventiveness in interpreting data and coming up with inferences and theories. In short, they viewed it as being needed and used at every stage. Among them TE7 saw creativity in the very nature of science and thought that it is what makes science "science." TE10 pointed out that nobody could separate intelligence from imagination and creativity. TE8,

having agreed with TE7 and TE10, believed that science does not have limits in finding resources:

Interviewer: Creativity and imagination also have the connotation of creating something from the mind. Do you think creativity and imagination play a part in science in that sense as well?

TE8: It is quite normal to “create something from the mind” in science. Popper says that one of the important reasons for the improvement in science has been the ideas that were bravely put forward no matter how strange they were. I mean I may see something in my dream tonight or something strange pops up in my mind while I am walking then I may try to test it with adequate methods. That is, it does not matter where this idea comes up, everything is possible.

Furthermore, many participants presented inadequate conceptions about the empirical NOS. Although the empirical base of scientific knowledge was commonly accepted by all participants, eight of them tended to believe that science and the development of scientific knowledge *solely* relies on direct evidence obtained from experiments or observations. They believed that science presents an objective and universal picture, thanks to the direct evidence it uses to “prove” its claims.

Art, for instance, is about personal understanding, imagination . . . if we compare them, science relies on conclusive and direct evidence. If something is true and there, you see the same thing as I do. (TE1.1: 11.1,4,5)

(About the structure of the atom) . . . it means that they [scientists] saw it. I did not see because I did not use, err, what they call it . . . yeah, ultra [electron] microscope. But I believe that scientists saw it so that they can talk about its structure. (TE6.1: 31.1,2,3)

This belief highlighting science’s heavy reliance on direct evidence was probably the most influential factor affected these participants’ perceptions about the place of inference and theoretical entities in science. Indeed, almost all of these participants articulated their suspicions about some of the scientific disciplines or research areas where there is a shortage of direct evidence. The commonly used example was the theory of evolution.

I mentioned about the importance of evidence and experiments in science, in the case of the theory of evolution there is no possible way to conduct experiments. When this is the case it could be said that it is dangerous or not suitable to define the theory of evolution as a scientific theory . . . (TE5.1: 32.2,3)

The theory of evolution cannot become a scientific law, because you cannot prove it . . . (TE13.1: 33.1)

By comparison, the group’s percentages were much higher in some aspects of science, such as *the nature of scientific theories* and *the subjective NOS*. Overall agreement about some of the statements was remarkable: agreement was 100% about the tentative nature of scientific theories, involvement of imagination and creativity in science, and the role of new evidence in theory change. Furthermore, more than 85% of the participants agreed on the societal influences on science.

Individual Performances

As mentioned, one can also see each individual’s score by looking at the bottom of the table. As seen in the table, individual percentages varied from 14% to 100%.

The analysis revealed that three participants' (TE1, TE6, and TE15) overall percentages were approximately or less than 30%. During the interviews, these participants continually presented inadequate conceptions about science such as their belief in science's reliance solely on direct evidence and their understanding of theory as an unsubstantiated idea. Interviews also revealed some crucial misunderstandings in their conceptions, such as their belief in the hierarchical relationship between scientific theories and laws. In the light of this evidence, it is clear that these participants have "naïve" views about NOS.

TE6 could be presented as a typical representative of this group of participants in certain ways in terms of describing science; on the other hand, he also had one of the most interesting approaches. (See Figure 3 for TE6's cognitive map on science.) His overall percentage was

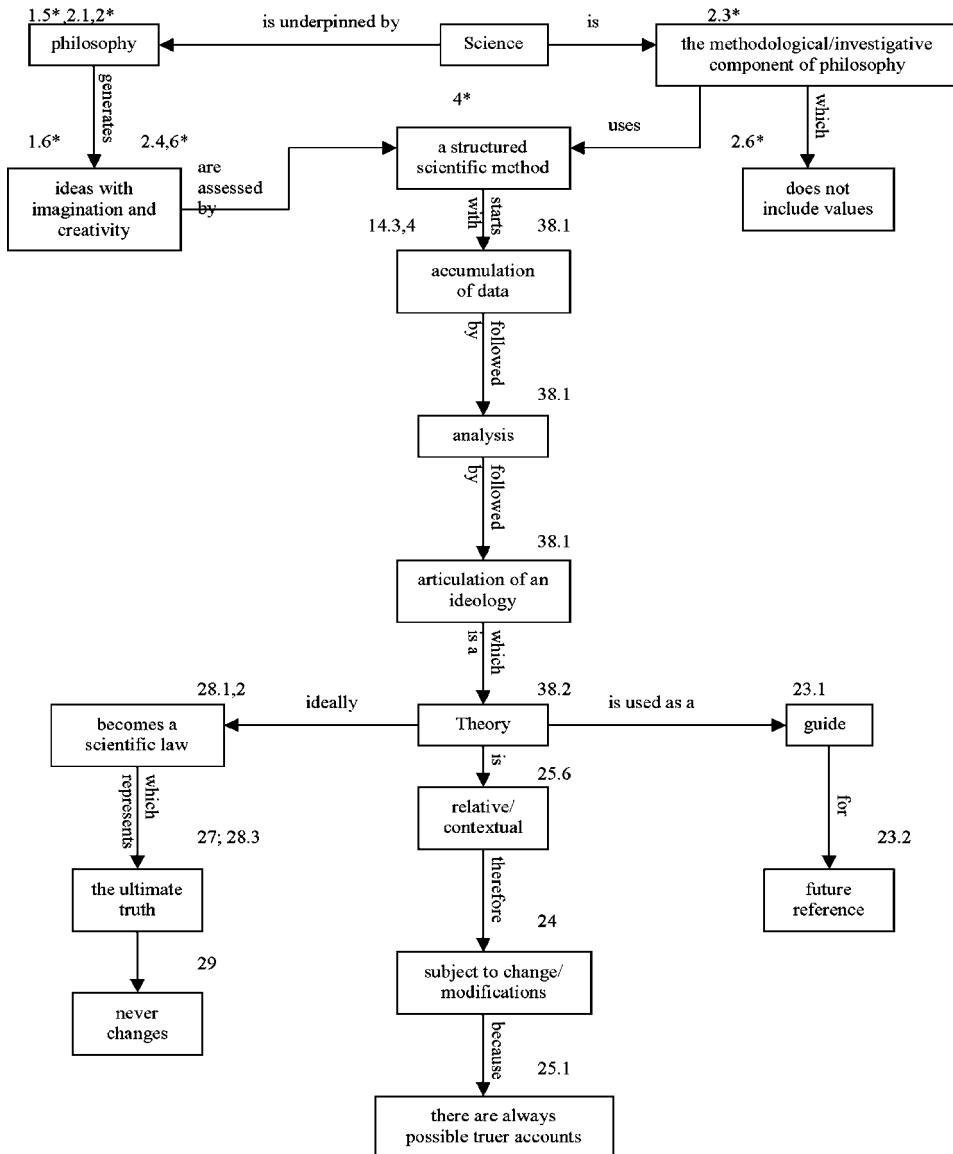


Figure 3. TE6's cognitive map on science.

32%, which is the highest in the naïve group (see Table 3). From this point of view, the reader may argue that he falls closer to the eclectic group with this percentage, however, as explained in the following, his crucial misunderstandings and mostly inconsistent views forced the researcher to list him in this group.

He believed that science is the only way to reach the “ultimate truth.” This ultimate truth might be out of reach of science at the moment; thus, reaching this truth will be step-by-step, revealing the truer accounts. These truths represent the rules and principles leading us to “happiness of mankind.”

Science must set the rules at every stage of life, for example, from the way of talking to each other to responsibilities of individuals in a society. (TE6.1: 12.5)
 . . . bringing human relations in a flawless level or closer to the perfect, for example, is the responsibility of science . . . (TE6.1: 13)

In this depiction, scientific laws represent the ultimate truth, whereas scientific theories are perceived as “relatively” or “contextually” true and, therefore, subject to change. He claimed that they remain theories because there is some refuting evidence against them or there is a shortage of concluding evidence to prove them.

. . . why does a theory fail to become a law? Because there are some refuting evidences that could falsify that theory, therefore it cannot become a law. (TE6.2: 6.2)

Therefore, he saw theories as temporary in nature:

As I said before, I believe that there are always truer accounts . . . therefore I see a theory as a temporary thing. (TE6.1: 25.1,4)

However, he was not always consistent in these ideas. For example, in spite of his strong “scientific” approach mentioned above where he declared science as the only and indisputable way of improving and regulating human life, in some parts of the interviews, where he was presented with some scenarios where different scientists come up with controversial explanations regarding a natural phenomenon, he accepted that science sometimes may fail to accomplish this task. In such instances he approached the issue from a relativist point of view that there are no demarcations to be drawn between scientific and other forms of knowledge. In these instances, he used the “politics” metaphor in order to explain that values influence decisions about which explanation to believe. An instance of this is his response to the question about the existence of various explanations for the extinction of dinosaurs:

. . . This shows that science does not answer all questions, sometimes you need to believe one of the explanations presented to you . . . it is like politics, you choose certain beliefs and go in that direction . . . (TE6.1: 34.1,4)

Various times in the interviews he expressed the view that he saw philosophy as a major component of science and that philosophy and science go hand-to-hand. Accordingly, as can be seen in his cognitive map, philosophy constitutes the base where “the ideas [theories] are generated by philosophers using imagination and creativity.” Science, in this framework, constitutes the methodological or investigative component where these ideas (theories) are put under test and experimentation using a structured scientific method.

. . . When we think about science as a methodology it becomes a rational act and does not include values, that which includes values is philosophy . . . (TE6.2: 2.6)

By comparison, four participants' (TE7, TE8, TE10, and TE11) percentages were remarkably high, with TE8 scoring 100%. It is worth mentioning that these four participants' combined total score (81/88) constituted almost half (45%) of the overall percentage of the group, which is 55% (180/330).

The consistency in their beliefs about NOS aspects throughout the interviews is important to note. They provided various examples in response to the questions and presented a comprehensive understanding of science throughout. More importantly, they did not only hold adequate understandings regarding all or most aspects of NOS but they were also aware of various alternative conceptions about NOS aspect in consideration. These participants were clearly "informed" about NOS.

TE8 typifies this group of participants. (See Figure 4 for TE8's cognitive map on science.) Like the other members of this group, he described science as "a" way of knowing among others. He contrasted science with religion to explain the difference of science.

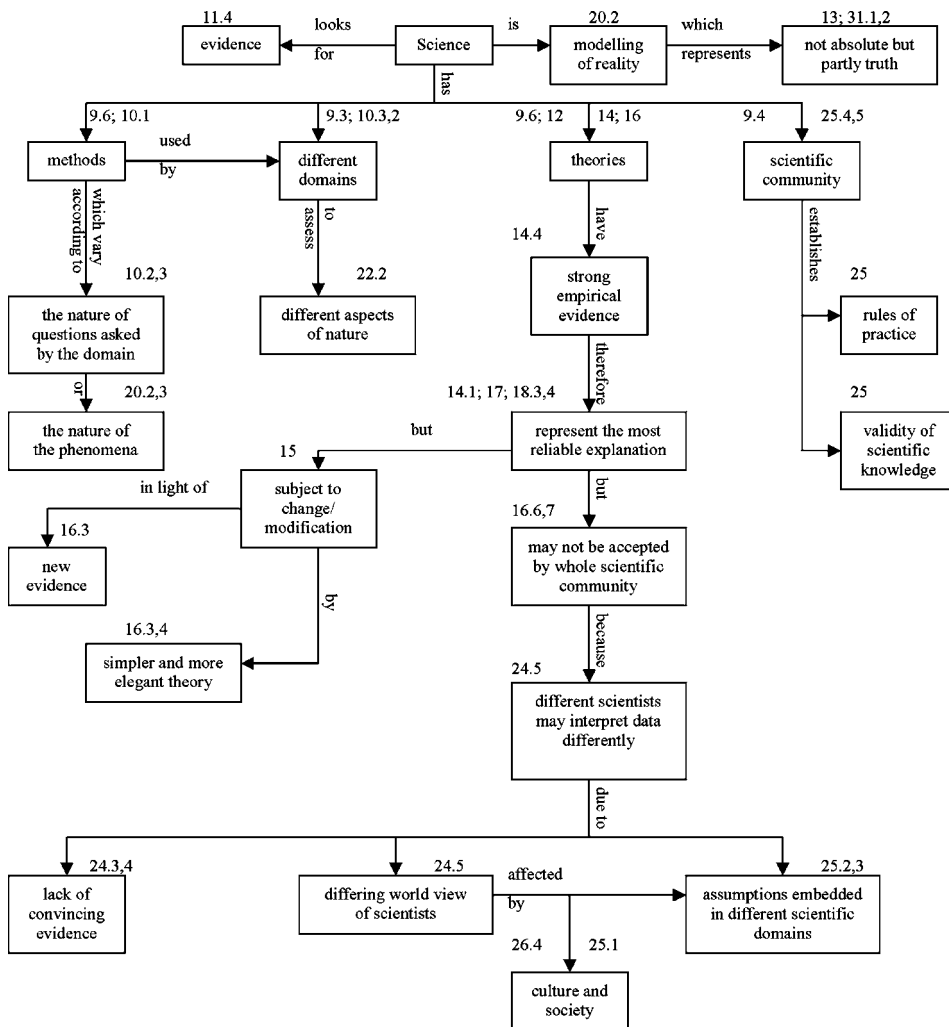


Figure 4. TE8's cognitive map on science.

Knowing and believing, these are two different words and concepts, there is a huge difference between them. When you talk about religion, [pause], religion is dogmatic, I mean you accept it, you do not discuss or test the validity of assumptions embedded to it . . . But science does not accept the effects of supernatural powers on nature, it looks for evidence. (TE8.1: 11.1,2,4)

He felt that it is impossible to define science in one sentence; he listed several aspects that any activity should have to be called science.

To be counted as science there must be a domain, a knowledge domain . . . then there is a need for community, consisting of scientists . . . such as biologists. Nevertheless, there must be methods, techniques and theories that are specific to that scientific discipline . . . (TE8.1: 9.4,5,6)

He perceived the aim of science as to clear our understanding about natural phenomena. To him, science uses models in this effort. He believed that although models (that is scientific knowledge) that science produces represent the most reliable explanation in light of our knowledge, nevertheless they are tentative and open to change and development. He explained that the development of the atomic model by modifications is an ideal example, indicating that scientific knowledge is not absolute.

. . . there are models in science. Modelling constitutes a major part of science, so this is [Atomic theory] a model that could help us understand reality. As you know there have been many atom models . . . (TE8.1: 20.2,3)

He rejected the view that there is one scientific method. However, he explained that he also is not comfortable with the relativist approach, which claims that the chosen method is relative to interests, people, and circumstances. Instead, he believed in a middle way that there are methods and standards in science, but that they can vary from science to science. That is, he saw method as related to paradigm or scientific discipline.

You may remember, when I was trying to define science I used “methods” instead of “a method.” Different disciplines use different methods, the methods that physics uses is not the same as those of biology. They cannot be the same considering the differences in the nature of the subject and the questions asked in these disciplines. (TE8.1: 10.2,3,4)

Having emphasized the well-sustained nature of theories, TE8 explained his thoughts about theory change that has parallels with his views on the tentative nature of science. He believed that theories are supported by strong empirical evidence; therefore, they represent the most reliable explanation about natural phenomena. However, he explained that no matter how strong and well sustained a theory may be today, it is always subject to change. He listed some of the reasons playing role in theory change:

There could be many reasons for that, for instance, if you agree with Thomas Kuhn, a paradigm shift takes place. The reason could be the emergence of new empirical data or a new explanation from a different point of view. A simple and more elegant theory may emerge. (TE8.1: 16.1,2,3)

He believed that the scientific community plays a vital role in deciding the validity of a new theory. He explained that the new theory is tested and discussed in this community and the acceptance of the new theory does not usually happen immediately.

... I talked about a scientific community, not all members of this scientific community change their ideas and practices when a new theory emerges. There is always debate in science and scientists never agree on a theory. Maxwell says that the reason why theories die is because scientists who support them die. (TE8.1: 16.6,7,8)

He saw the reasons for disagreement regarding the validity of the new theory as being a result of different interpretations of new evidence by different scientists. He explained that the nature of new evidence and scientists' professional and cultural backgrounds play a significant role in their interpretation of evidence.

The remaining eight participants demonstrated an "eclectic" understanding regarding NOS. Their percentages varied between 34% and 61%. Here, the term "eclectic" is used to describe a belief system that is derived from various philosophical positions regarding NOS. The analysis of the data indicated that deriving ideas from various philosophical positions regarding NOS without proper reflection usually caused some inconsistencies and conflicts in these individuals' views of which they were not aware. Therefore, in this study, an "eclectic view" refers to *a view about NOS which was derived from various philosophical positions and therefore containing inconsistencies and conflicts within*. Indeed, this group of views is usually characterized by inconsistent and often conflicting statements that were made about NOS aspect in consideration. For instance, a view that while appreciating an inferential but well-sustained nature of the structure of the atom yet which rejects the theory of evolution due to the absence of direct evidence was placed in this group.

It is possible to present TE13's beliefs about science as a case to understand this group's approach to scientific enterprise. (Figure 5 illustrates TE13's cognitive map on science.) TE13 did not regard science as "the" way of knowing. Rather she saw it as "a" way of knowing among others but pointed out the reliability of scientific knowledge. She believed that science differs from other forms of knowledge by relying on evidence and avoiding dogmatic assumptions. As seen in her cognitive map, she described science as an effort to understand life.

... Science is an effort to understand life by observation and gathering evidence ... In religion, however, knowledge is already there, there are rules and you are required to accept and obey them. (TE13.1: 16.2,4)

What characterized her beliefs about science, however, was the inconsistency between her beliefs. Early in the first interviews she continuously spoke of the importance of observation and direct evidence in science and scientists' responsibility to "prove" their claims. When she was asked, later in the interview, what she had meant by "proving," she explained:

Interviewer: Several times you spoke of "proof" and "proving." What did you mean?

TE13: [pause] I meant something that, eh, I think the right word is "supports," yes, something that supports our ideas ... as it is in the case of fossils of anthropologists, they have theories about the past and they say "this fossil is supportive evidence for my ideas," but it is not the 100% truth, it is just something supporting the idea.

As mentioned, she was not always consistent in her ideas and this usually made it very difficult to assess her beliefs. For example, while she talked about the supportive role of fossil evidence, later she rejected this and stated that scientific claims about the things that happened in the past cannot be supported or proven by any evidence because we cannot see it with our eyes.

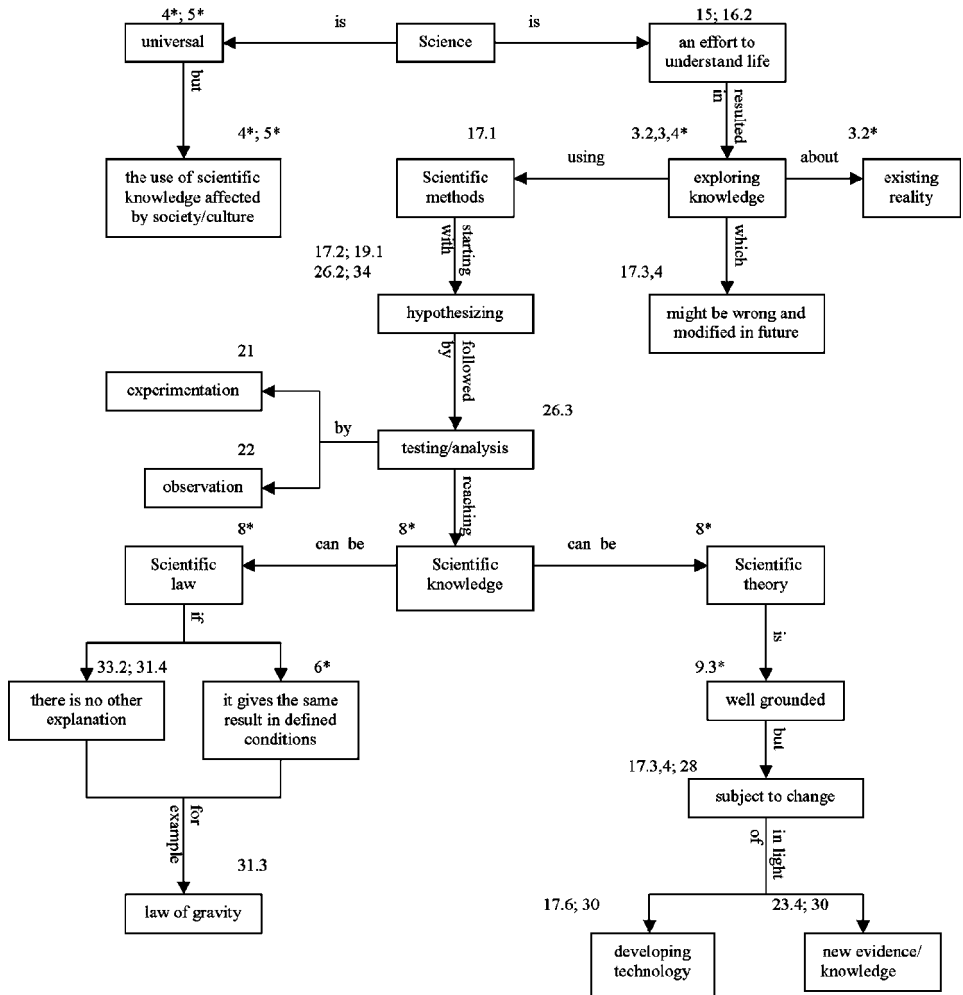


Figure 5. TE13's cognitive map on science.

If you make a claim without direct and conclusive evidence, then, I think it is not science. On the other hand, there are some passionate individuals, some scientists, who want to become famous by dealing with these speculative issues . . . Why on earth are these scientists always interested in dinosaurs? It is just a speculation, you cannot prove it . . . They don't even know anything about the climate they [dinosaurs] lived in . . . (TE13.1: 42.1,2,3,4,5)

However, in response to the very next set of questions about the inference and theoretical entities in science she explained:

(About the structure of the atom)
 . . . [Having mentioned that we cannot see the atom] They [scientists] have come up with this structure using the existing indirect evidence. (TE13.1: 37.1)
 (About the concept of "Species")
 . . . we classify them in order to enhance our understanding. It does not mean that there is such a thing in nature. (TE13.1: 39.1,2)

So, having analyzed her first interview, in the second interview, I presented her with these inconsistent statements.

Interviewer: In some questions at our first meeting you expressed your doubts about the investigation methods and findings of some disciplines and their theories, such as the theory of evolution and the theories about the extinction of dinosaurs . . .

TE13: Right, I said that we could not reach the truth about the beginning of life, because it happened a long time ago, we cannot see, therefore it is difficult to prove.

Interviewer: Yes, on the other hand, you claimed that atomic theory is a well-sustained theory. But, both theories are about unobservable things and, in your words at the first interview, “estimations” of scientists relying on indirect evidence . . .

TE13: But, for example you mentioned about volcanoes, meteors and the extinction of the dinosaurs. There is no evidence . . . no, of course some evidence exists, but . . . they are different . . . I think it is possible to develop and support atomic theory; it is easy to believe it. Because the extinction of dinosaurs is about a thing that happened millions of years ago, I could not be sure that the fossils that I have are from that period of time. In contrast, in the case of atomic theory you might find new evidence with the development of technology. I mean, I don’t know . . .

Another inconsistency in her beliefs was about the relationship between theories and laws. In the first interviews, she described scientific laws as proven theories and spoke of a hierarchical relationship between the two, laws being superior. Having reflected on her explanation at the first interview in which she defended a possible hierarchical relationship between the two, TE13 expressed her doubts about this at the second interview.

TE13: . . . OK, a hypothesis may become a theory, but, I am not sure now as I was at the first interview about theories’ transformation to laws.

Interviewer: Do you think that they are different forms of scientific knowledge?

TE13: I mean there is not a hierarchical relationship.

Interviewer: So, what do you think is the difference between them?

TE13: I don’t think that you follow a different route to reach scientific law than you do to reach scientific theory. I suppose that hypothesising is the first step, it is just an idea in your mind, it becomes theory by testing . . . theory . . . law . . . between two . . . I don’t know . . .

She believed that there is a method in science that scientists follow and therefore rejected the involvement of subjectivity in science. Consistent with these beliefs she believed in the universality of science and rejected social cultural influences on science.

Science is not and should not be affected by society. (TE13.1: 43.1)

She did not completely deny the relationship between science and society. She believed that scientific processes are independent from cultural influences. But society has the authority on how and in what ways the products and knowledge that science presents will be used.

TE13: Science is universal and is not affected by society. But “the use of science” is a different matter.

Interviewer: Do you mean that the generation of scientific knowledge and the use of it are separate issues?

TE13: Yes, the content and process of science are independent of any influence. But how, when, where we use the knowledge generated by science and the explanations presented will be the decision of society.

DISCUSSION

Research literature clearly indicates that students, teachers, lay people, and even scientists do not possess adequate conceptions about many aspects of NOS (Lederman, 1992; McComas, 1998). Similarly, this research revealed that the majority, if not all, of the Turkish PSTEs participated in this study also held some inadequate conceptions about NOS.

The fact that many participants held "naïve" or "eclectic" beliefs about NOS may be a result of their own experiences of school science in Turkey. As discussed earlier, many factors in Turkey (e.g., content-based curriculum and the existence of university entrance examination) will have contributed to the development of inadequate beliefs concerning science. As the products of such an education, it is not surprising that these participants were left with a range of misconceptions or naïve beliefs about NOS.

The participants' university experiences as undergraduate students might have also contributed to their poor understanding of NOS. The individual level analysis made it possible to assess the relationship between the participants' academic backgrounds and their beliefs about NOS. Although research on teachers' beliefs indicates that academic background variables are not significantly related to their conceptions of NOS (Lederman, 1992), the results of this research tentatively challenge such a conclusion.

The results revealed that the participants with an engineering background held mostly naïve or eclectic beliefs about NOS whereas the participants with science and education backgrounds generally possessed relatively more informed conceptions (see Table 4). As illustrated in the table, two of the three participants (TE1 and TE6) whose beliefs about NOS were identified as "naïve" had engineering backgrounds. By comparison, three of the four participants (TE11, TE10, and TE8) with an informed understanding of NOS were from an education background. From a different point of view, the average percentage of the five participants with an engineering background was 36%, the three participants with a science background was 61%, and the seven participants with an education background was 64%.

TABLE 4
The Comparison of the Participants' Academic Backgrounds and Beliefs About NOS

Academic Background	Participant	NOS Understanding	Individual Performance	Average
Engineering	TE1	Naïve	3/22 (14%)	36%
	TE6	Naïve	7/22 (32%)	
	TE13	Eclectic	8/22 (36%)	
	TE4	Eclectic	9/22 (41%)	
	TE12	Eclectic	13/22 (59%)	
Science	TE2	Eclectic	11/22 (50%)	61%
	TE5	Eclectic	11/22 (50%)	
	TE7	Informed	18/22 (82%)	
Education	TE15	Naïve	4/22 (18%)	64%
	TE3	Eclectic	8/22 (36%)	
	TE14	Eclectic	12/22 (55%)	
	TE9	Eclectic	13/22 (59%)	
	TE11	Informed	20/22 (90%)	
	TE10	Informed	21/22 (95%)	
	TE8	Informed	22/22 (100%)	

These findings may be explained by the way science (implicitly or explicitly) is portrayed in engineering departments. Courses in these departments require students to rely on precise measurements for successful applications and the use of an analytic and structured method to obtain necessary data. It is possible that this situation influences students in engineering departments to associate science with a positivistic view of science in which science is viewed as providing absolute knowledge through a structured method. The results seem to support this explanation. As seen in Table 3, all participants with an engineering background claimed that there is a universal scientific method and believed in the correctness of scientific knowledge.

Consistent with previous research (e.g., Lakin & Wellington, 1994; Mellado, 1997), for almost all participants with a naïve or eclectic beliefs about NOS, a lack of previous reflection regarding NOS was detected. This lack of reflection was possibly another reason for their inadequate beliefs, their use of clichés, and their conflicting ideas (Mellado, 1997). This finding is also supported by the fact that the four participants with informed understandings attended an HPS course and/or were personally interested in the philosophy of science or social science and had engaged in reading in these issues.

CONCLUSION AND IMPLICATIONS

One of the most important goals of science education is to promote scientific literacy within society in order for its members to contribute in decision-making processes with regard to scientific knowledge. It is without doubt that the success of such a movement anywhere in the world depends on the existence of quality and knowledgeable science teachers. Research evidence indicates that many preservice science teachers in Turkey, like their counterparts all around the world, enter teacher education programs without a clear conception of the nature of their own discipline (Yalvac & Crawford, 2002). Science teacher education programs emerge as the last opportunity to challenge and change inadequate beliefs about NOS (Abd-El-Khalick & Lederman, 2000). In this sense, the fact that many of the PSTEs who participated in this study were found to be holding either naïve or eclectic beliefs regarding NOS is worrying and has serious implications for both the Turkish teacher education and teacher education in general. It can be argued that such inadequate beliefs may potentially show its negative effects at least at two levels: *the practical level* and *the policy level*.

At the practical level, their naïve and inconsistent ideas may show their effects in classroom practice. They could display their naïve and inconsistent ideas implicitly or explicitly in their own classrooms or during supervisions with preservice teachers. Research evidence shows that students are positively affected by their teacher's implied philosophy of science even if the teacher does not attempt to do so explicitly (Tobin & McRobbie, 1997). This implies that the participants' naïve and inconsistent ideas about science and scientific knowledge may negatively affect their students' ideas, let alone improve them.

Furthermore, science teacher educators are primarily responsible for designing the curriculum in science teacher education programs as well as delivering it. Research evidence indicates that science educators with naïve and eclectic NOS understanding did not perceive the teaching of NOS as a primary goal in science education (Irez, 2004). As a result of this lack of attention, they may not prioritize the explicit assessment and development of preservice teachers' conceptions of science and therefore may not open necessary courses in their programs. This would mean that the vast majority of newly trained science teachers will go out into schools with unexamined and unclear conceptions of NOS.

On the other hand, the participants' inadequate understandings may well show their negative effects at the policy level. One of the important responsibilities of teacher educators,

arguably, is to lobby for needed reforms in education in the light of research evidence. There is no doubt that these PSTEs, when they return to Turkey, will have an influence on the discussions regarding future reforms and contribute to policy-making in science education. The potential danger here is that teaching and learning about NOS may fail to become a necessary component of science education curriculum in Turkish schools due to a lack of awareness of the importance of this by many science teacher educators. This would inevitably jeopardize the promotion of scientific literacy in society.

These may sound like worst-case scenarios, but the danger potentially exists. Fullan (1991) stresses that it is not possible to develop or reform institutions without developing the people in them. From this perspective, unless these PSTEs develop informed understandings with regard to NOS, the 1998 teacher education reform may fail to have a noticeable impact on the current profile of science education in Turkey.

I would like to remind that the participants of this study were not practicing teacher educators; instead, they were graduates preparing to be teacher educators. Given the complex relationship between beliefs and how they transpire into practice, one should approach the above discussion on the implications of the research with caution. Clearly, further research in this particular area of science education is needed. In this sense, longitudinal studies that assess the beliefs of preservice teachers/teacher educators and pursue how these beliefs translate into their classroom practices and into the nature of the curriculum they develop in their first years of teaching would be valuable. Such studies would also inform us about the "wash-out-effect" (Zeichner & Tabachnick, 1985) of the first years in the profession, which represents the collapse of the missionary ideals by the harsh-and-rude reality of everyday classroom life (Veenman, 1984) on educators' beliefs about NOS.

What the findings of this research suggest is that close attention should be paid to the preservice preparation of science teacher educators. Existing research literature does not tell us much about the preservice education of science teacher educators (Craven, 1998). Therefore, research is needed on the structure and effectiveness of the programs that graduate students follow to become science teacher educators. Such an examination should also take students' experiences in these programs into consideration.

Reflection should lay at the core of preservice education of science teacher educators. PSTEs, like preservice teachers, enter graduate level programs holding ideas, beliefs, and values (Abell & Bryan, 1997; Lainer & Little, 1986). Therefore, PSTEs should be encouraged throughout their studies to explore these preexisting beliefs in order to develop them. Such reflection is especially crucial if PSTEs are to improve their understandings of NOS as this requires a critical deliberation of one's own beliefs (Irez, 2002). Indeed, for almost all participants holding naïve or eclectic beliefs about NOS in this study, a lack of previous reflection regarding NOS was detected. As explained earlier, this lack of reflection was possibly the most important reason for their inadequate beliefs, their use of clichés, and their conflicting ideas (Mellado, 1997). An ideal environment for this reflection would be a special course on NOS. The necessity of such a course in science teacher education has already been emphasized by many researchers in the last decade (e.g., Eichinger et al., 1997). Similar courses should be made available for PSTEs.

In summary, PSTEs need to be aware of any inconsistencies and misconceptions they may have regarding NOS and what the effects of these inconsistencies might be on their practice. Such a reflection would prepare them for supporting preservice teachers who will also exhibit inconsistencies and misconceptions in their practice. Without a doubt, science teacher educators with differentiated and integrated understanding of NOS will have greater ability than those whose understanding is limited and inconsistent, to plan and deliver lessons that help science teachers develop deep and adequate understandings.

On the other hand, the fact that PSTEs may have poor understandings with regard to NOS raises questions about practicing science teacher educators' understandings of science. Especially in countries like Turkey, where teacher education institutions are dominated by academics with pure science background, it is likely that practicing science teacher educators also have inadequate understandings of NOS. This possibility calls for attention to the in-service education of science teacher educators.

As Day (1987) argues, professional development in educational settings cannot be forced, "it is the teacher who develops (active), not the teacher who is developed (passive)" (p. 219). Therefore, the need for change must be internalized by the teacher if effective change is to occur (Day, 1987). Furthermore, Fullan (1992) points out the necessity of a collaborative environment for effective change. From this perspective, developing practicing science teacher educators' understandings of NOS requires a collaborative work environment that is committed to professional development. For science teacher educators, such an environment can be achieved at two levels: at the institutional level and at the national level. Institutions that value collaboration and sharing ideas would provide opportunities for those whose understandings are incomplete or inadequate to become aware of the weaknesses in their practices and understandings and develop them. National organizations of science teacher educators aiming to promote collaboration among their members would also provide opportunities for professional development. With regard to NOS, special interest groups devoted to NOS within these organizations would act as pressure groups that emphasize the importance of the teaching and learning about science in science education and thus call members to explore, reflect upon, and develop their understandings of NOS. Such an initiative could be very significant for the Turkish context. A special interest group within one of the national associations of science teacher educators would keep up the pressure on the members to develop themselves with regard to NOS. Such an attempt would also be useful (and necessary) to attract the policy-makers' attention to the importance of the teaching and learning about NOS if scientific literacy is to be achieved in the nation's schools.

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