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Duygu Metin[1], Hamide Ertepinar[2]
[1]Abant Izzet Baysal University
[2]Istanbul Aydin University

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Abstract

The purposes of the present study are to elicit pre-service elementary science teachers' scientific and pseudoscientific beliefs about earthquake and to make inferences about their understandings of science. Although the subject of earthquake is not a pseudoscientific area, some pseudoscientific beliefs related to earthquake were used in this study. Forty-one pre-service elementary science teachers participated in the study voluntarily. The open-ended questionnaire involving eight items related to earthquake were administered to pre-service science teachers. The qualitative data were analyzed by applying interpretative analysis. The results of the analysis revealed that some of the pre-service science teachers had pseudoscientific beliefs about earthquake contexts, although they had science education background. Additionally, rest of the pre-service science teachers could not present any scientific evidences about why they are in favor of scientific explanation or why they do not believe pseudoscience. The pre-service science teachers were not able to articulate their knowledge learned in NOS (Nature of Science) course when they reason about pseudoscientific beliefs about earthquake. Therefore, it would be recommended that understanding of NOS and conceptualizing demarcation criteria between science and pseudoscience should be intended to be developed within the subject matter of science and it should be integrated into other courses by explicitly emphasizing in real science contexts.

Introduction

The development of responsible citizenship has been essential and continuous to be a fundamental goal of every country. Definitely, science literacy is a vital attribute of being a well-educated citizen. Since one of the major issues in science education is to train science literate individuals who are able to understand what science is, how science is done, and what the inherent values of science are; qualified science education should be one of the most important contributors of good citizenship. Accordingly, science literacy requires not only being able to comprehend the nature of science (NOS), but also being able to demarcate science from pseudoscience. For instance, Hurd (1998) identified some characteristics of science literate individual; distinguishes theory from dogma, and data from myth; senses the ways in which scientific research is done and how the findings are validated; distinguishes science from pseudoscience such as astrology; knows how to analyze and process information to generate knowledge that extends beyond facts; distinguishes evidence from propaganda, and knowledge from opinion. Additionally, Martin (1994) referred recognizing and evaluating pseudoscientific claims as a part of science literacy and emphasized that "learning to think critically about pseudoscientific and paranormal beliefs is part of being scientific" (Martin, 1994, p. 357).

Good and Slezak (2011) stressed the importance of pseudoscientific beliefs in science literacy by asking that "can people be considered as scientifically literate if they are unable to recognize common forms of pseudoscience?" (p. 401). More generally, science literacy describes what is included in science, what is investigated scientifically, which scientific process is used and what criterions are used to accept something as scientific. Demarcation science from pseudoscience can be seen as basis for understanding NOS. For instance, understanding empirical NOS requires using scientific data and evidence effectively in constructing scientific knowledge that extends beyond facts. But, having pseudoscientific belief, for instance believing astrology by using only personal experience as if it were scientific area indicates the absence of understanding the empirical NOS.

Demarcation of Science from Pseudoscience

Although science and pseudoscience seem to have some similarities, they are absolutely different from each other. Pseudoscience can be defined as systematic body of propositions, practices, and attitudes that gives the appearance of being science (Martin, 1972). Similarly, Shermer (1997) defines pseudoscience as claims that they appear scientific although they lack supporting evidence and plausibility. Many things which are done in the name of science in everyday life such as astrology (Kallery, 2001), water dowsing (Afonso and Gilbert, 2010), crystal power (Preece and Baxter, 2000), telepathy, acupuncture, and faith healing (Martin, 1994) have been characterized as pseudoscience.

Students' pseudoscientific beliefs are important but neglected aspect of science education. However, there is remarkable reason to suppose that pseudoscientific beliefs are widespread among students. There are well-documented evidence indicating that students in different age groups believe different kind of pseudoscientific beliefs such as astrology (DeRobertis & Delaney, 2000; Preece & Baxter, 2000), palmistry and crystals (Preece & Baxter, 2000), ghosts and witchcraft, acupuncture and telepathy (Lundström & Jakobsson, 2009), water dowsing (Afonso & Gilbert, 2010). The social embeddedness of science and pseudoscience would be important cause of widespread belief in pseudoscience in the society. Science cannot be imagined without the influence of the society in which it's done. Generally, scientists bring and reflect in their work the values and prejudices of the cultures in which they live. In parallel, pseudoscientific beliefs and understandings are spread out by culture. People hear scientific, pseudoscientific, and even religious arguments about pseudoscientific issues throughout their lives from their teachers, relatives, and friends. As a result of this social effect, some pseudoscientific beliefs became widespread in the society. According to Whittle (2004), the society creates and maintains such a belief through cultural knowledge, cultural artifacts, and cultural behaviors. People are taught about beliefs and practices of our culture.

Moreover, there is another reason which made current condition worse with regard to pseudoscience. That reason is mass media influence. Pseudoscientific applications are commonly stressed by many books, television programs, and advertisements. These pseudoscientific applications are generally propagated by well-organized groups with the aim of substantial commercial interests in popular media (Castelao-Lawless, 2002).The impact of mass media regarding persuasion of society constitutes undesirable public understanding of science. According to Castelao-Lawless (2002), impact of mass media mislead the public about image of science that all ideas can be seen scientific as long as it conducted in the eye of the beholders and it's accepted by some group of people as such. Since this image of science imposes public scientific relativism, it's accepted one of the most important limitations in achieving desirable NOS understanding. Thus, pseudoscientific enterprises and beliefs can be concluded as a threat to public understanding of science and public itself who are supposed to be well-educated citizens.

To emphasize negative impact of pseudoscience on understanding of science, Martin (1994) stated that pseudoscientific and paranormal beliefs are serious obstacles for understanding the theory and its evidential support. These serious obstacles are also indicators of being misinformed, failing to critically evaluate alternative hypotheses, and neglecting of the essential principles of scientific investigation. Therefore, these obstacles originated from pseudoscientific beliefs impede the understanding the process of science and how scientific knowledge constructed in the light of scientific data and evidence.

It's important to understand the distinction between science and pseudoscience in order to effectively comprehend and gain a true understanding of science. Nevertheless, it's not easy to demarcate science from pseudoscience. There are no clear-cut demarcation criterions for distinguishing scientific area from pseudoscientific one among science philosophers (Afonso and Gilbert, 2010). Although issue of demarcation is traced back to ancient time, many contemporary philosophers have tried to solve the demarcation problem according to their own paradigmatic perspectives over a hundred year. Popper (1963) proposed falsification criterion and stated that criterion of the scientific status of a theory is its falsifiability, refutability, and testability. According to Kuhn (1996), in contrary to Popper's criterion, science takes place between the unusual moments of scientific revolutions, thus Kuhn's demarcation criterion is based on existence of paradigm which is shaped by scientific revolutions. Recently, Martin (1994) based his argument on the difference between standard of proof and evidence used in pseudoscience and science. He argued that science critically tests its theories and hypotheses and modifies them in the light of the evidence, but pseudoscience doesn't. Radner and Radner (1982) expressed that pseudoscientists were generally interested in volumes and quantity of evidence and they tended to use selective data which confirm their ideas and pseudoscientists might also have tendency to use personal experience and anecdotes as evidence and might have tendency to use eyewitness evidence.

According to above arguments, it's obvious that demarcation problem between science and pseudoscience is continuous and philosophical issue. It's not easy to be comprehended by students. Although the demarcation between science and pseudoscience doesn't draw required attention from science teachers and educators, there are some attempts both to elicit students' available pseudoscientific beliefs and their ability of demarcation.

Research on Pseudoscientific Beliefs

When we look at the literature, consistent evidence is available showing that pseudoscientific beliefs are widespread among general population, students, and teachers. Most of the evidence coming from literature is based on surveys which question students' belief-driven decisions in pseudoscience. For instance, NSF (National Science Foundation of US) has surveyed public scientific literacy by measuring their ability of demarcation science from pseudoscience since 1979. One of the recent published report of NSF showed that more than half (%54) of the youngest informants were more likely to say astrology was very or sort of scientific.

In educational manner, belief-driven surveys about pseudoscientific, paranormal or superstitious beliefs constitute big part of the literature and the astrology is the most questioned topic in these surveys. By using astrology, Kallery (2001) investigated 103 Greek early-years teachers' opinions and attitudes toward astrology and tested their awareness of the distinction between astronomy and astrology. Result of the study revealed that majority of the teachers view both astronomy and astrology as scientific, and they cannot distinguish science and pseudoscience. Interestingly, almost half of the teachers weren't aware of what astronomers can or cannot do, and quarter of them believed that astronomers can predict people's character and future as astrologists do. In another study, Preece and Baxter (2000) surveyed 2159 secondary school students' pseudoscientific beliefs in UK by using a survey which included a combination of pseudoscientific issues such as astrology, palmistry, and crystals. In this study, students' scepticism and gullibility were examined through their responses to pseudoscientific issues. Researchers found that scepticism increased steadily as the grade level increased. Beside research studies conducted with teachers or secondary school students, the related literature has generally informed us about university students' beliefs about pseudoscience. For instance, DeRobertis and Delaney (2000) conducted one of the largest surveys with Canadian university students to determine their attitudes toward astrology and to establish whether they are able to distinguish astronomy and astrology. The survey results indicated that more than 53% science students subscribed to the principles of astrology. Likewise, more than 44% science students were unable to distinguish astronomy and astrology. DeRobertis and Delaney (2000) interpreted these results as a serious problem with science literacy.

There are also some studies investigating relationship between belief in pseudoscience and science knowledge, attitude toward science, and scientific literacy. Most of them revealed that there is no relationship between science knowledge and belief in pseudoscience. Therefore, it is quite possible that those who have fairly sizable science knowledge can have belief in pseudoscience. For instance, Sugarmann, Impey, Buxner, Antonellis (2011) surveyed scientific knowledge and attitudes toward science of undergraduates from US with an assumption stating that students who know more science are less likely to subscribe to the principles of astrology, or be susceptible to the other forms of pseudoscience. Thus, their survey includes several questions which were designed to measure attitudes about science, perceptions of pseudoscience, and general scientific knowledge. Interestingly they found that beliefs in astrology aren't strongly linked to science literacy and is also relatively impervious to a college education. Similarly, Walker, Hoekstra and Vogl (2002) surveyed a total of 207 undergraduates to investigate the relationships between pseudoscientific beliefs and level of scientific knowledge in the U.S. They found no relation between level of science knowledge and scepticism regarding paranormal beliefs. They also stated that "it's possible for a student to accumulate fairly sizable science knowledge without learning how to properly distinguish between reputable science and pseudoscience" (p. 1). Consistent result was provided by Johnson. Johnson (2003) addressed the relationship among science factual knowledge, conceptual understanding of science, and belief in pseudoscience by comparing science majors and non-science majors. He used 30-question survey consisting of three types of questions. The result of the study showed that there was no apparent relationship between pseudoscience belief and understanding of scientific concepts and methods. Based on these results, it would be said that having a strong scientific knowledge base is not enough to keep away students from pseudoscientific beliefs.

Recently there are some other efforts to reveal the association of pseudoscience with other variables. Barnes, Abd-El-Fattah, Chandler, and Yates (2008) investigated pseudoscientific and paranormal beliefs of 362 university students from Australia. They found that 10% of them consistently rejected all six New Age (pseudoscientific) statements on the survey, and 1% consistently accepted all six statements. In all, 62% indicated agreement with at least one New Age belief. Additionally, it was found that New Age beliefs didn't relate to university year level, grade point average, anti-scientific attitudes, or dispositions to approach or avoid personal argumentation. Additionally, Losh and Nzekwe (2011) investigated 663 pre-service science teachers' views about evolution theory, intelligent design, and fantastic beasts in US. They used a survey including demographics and 88 knowledge and belief items. They found that pre-service science teachers rejected evolution, accepting Biblical creation and intelligent design accounts. Although gender, disciplinary major, grade point average, science knowledge measures were related to beliefs about evolution-creation, these factors were generally unassociated with the other variables.

Most of the previous attempts in literature depend on survey by which students' pseudoscientific beliefs especially related to astrology were elicited. The results of these surveys consistently showed that students, and even teachers subscribed pseudoscientific beliefs and they weren't able to demarcate science from pseudoscience. Although students and teachers have scientific knowledge, they would have difficulties to demarcate science from pseudoscience. Furthermore, they need to relate their knowledge about science with epistemological perspective of science, hence NOS. The NOS refers to epistemology of science, science as a way of knowing, or values and beliefs inherent to scientific knowledge and its development (Lederman, 2007). Understanding of NOS and ability of demarcation science from pseudoscience are complementary to each other. However, little has been done to provide specific information that goes beyond the eliciting students' beliefs about pseudoscience.

Recently, Afonso and Gilbert (2010) investigated the university students' NOS understanding by using water-dowsing issue as a pseudoscientific context. University science and non-science students were interviewed about their beliefs and explanations for "water dowsing", a pseudoscientific approach to finding groundwater. The demarcation criteria between science and pseudoscience and students' research designs into "water dowsing" were also enquired into. The results showed that many students believed in the working efficacy of water dowsing and stated pseudoscientific explanations for it. Furthermore, they were unaware of the demarcation criteria between science and pseudoscience, and designed naïve research studies to enquire into "water dowsing". Another study, performed by Turgut (2011), investigated whether a teaching context based on the issue of demarcation would provide a suitable opportunity for exposing and further developing the NOS understandings of individuals enrolled in a teacher education course. Astrology was used as a pseudoscientific context in this study. Results indicated that a learning intervention based on the issue of demarcation of science from pseudoscience proved an effective instructional strategy, which a majority of teacher candidates claimed to plan to use in their future teachings.

Using pseudoscientific issues such as astrology as a learning context provides authentic environment for learners to express their beliefs' patterns. Contrary to de-contextualized activities which intent to introduce NOS aspects, pseudoscientific context provides discussion basis for learners in order to explain their understanding of NOS. Thus, pseudoscientific context facilitates their understanding about science in more meaningful way. Pseudoscientific context also provides opportunity to elicit learners' understanding of science by using more familiar and social context while they are reasoning about them. Through debating about pseudoscientific issues, learners' views about NOS are elicited indirectly. While learners are talking about their impressions about pseudoscientific issues such as astrology, water dowsing, and healing, at the same time they consciously or unconsciously indicate their understanding about science and their criterions about to be accepted as scientific. Therefore, using pseudoscientific context provides researchers more authentic way to elicit learners' views about NOS in a real life context. For this reason, the purposes of the study are to elicit pre-service science teachers' scientific and pseudoscientific beliefs about earthquake and to make inferences about their understanding of science.

Although earthquake is not pseudoscientific area itself, some pseudoscientific beliefs about it are used in this study. There are some specific reasons of regarding earthquake as a pseudoscientific context. Primary specific reason is cultural familiarity of earthquake in Turkey. Turkey is located in seismic zone and is an earthquake-prone country. Many earthquakes frequently occur in Turkey. It is reviewed by Cagatay (2005) that 21 devastating earthquakes with 7 or greater magnitude occurred between 1912 and 1999. Thus, earthquake is a reality for Turkish people. Additionally, the present study was carried out in Bolu which is one of the most earthquake-prone cities in Turkey. Bolu experienced two devastating earthquakes on 17th August 1999 with 7.4 magnitude and on 12th November 1999 with 7.2 magnitude. For that reason, people hear scientific, pseudoscientific, and even religious arguments about it throughout their life from their teachers, relatives, friends, and mass media. As a result of the social effect, in the society it became a widespread belief that earthquake is related to solar eclipse or the appearances of the stars (Aksoy-Sheridan, 2007).

The other specific reason is that earthquake is a subject which might cause development of pseudoscientific beliefs due to its uncertain nature. Because of its power and devastating consequences, people try to make sense of earthquake in different perspectives. People's attempts for giving meaning to such natural disaster might direct them toward more pseudoscientific beliefs. Because of being one of the most-discussed subjects in mass media, these kinds of beliefs are supported.

Method

This study was qualitative in nature. The present study aimed at eliciting pre-service science teachers' scientific and pseudoscientific beliefs about earthquake and making inferences about their understanding of science. The qualitative approach is based on philosophy of postpositivism which basically states that each individual constructs his/her own understanding and it emphasizes the constructed truth. Thus, this study was directed by postpositivist worldview of the researchers. On the other hand, Merriam (2009) clarified the purpose of the qualitative approach by stating that "(1) how people interpret their experiences, (2) how they construct their worlds, and (3) what meaning they attribute to their experiences" (p. 23). In parallel to Merriam's (2009) viewpoint, the present study focused on how pre-service science teachers interpret their experiences about earthquake, what meaning they attribute to their observations about earthquake, and how they construct their understandings about earthquake; by using scientific way of knowing or pseudoscientific way of knowing.

Participants

Forty-one pre-service science teachers participated in the study voluntarily. They were at the last year of their education at a state university. Twelve of them were male and twenty-nine of them were female. Thirty-seven of them had experienced earthquake at least once in their life, but others didn't have any earthquake experiences. Through their education at the university, they had science courses such as chemistry, physic, biology, history of science and NOS, earth science/geology, and environmental science. In results section, pseudonyms were used in parenthesis to protect participants' identities.

Data Collection

A qualitative methodology was conducted in this study. Pre-service science teachers were administered an eight-item open-ended questionnaire about earthquake.

Questionnaire

After selecting earthquake context because of aforementioned reasons, eight questions which investigate pre-service science teachers' knowledge about earthquake and their conceptions of science and scientific knowledge were written by the researchers. All questions were analyzed by five experts who are experienced in science education. Based on the feedbacks from the experts, some questions were improved and some other questions were detailed by inserting sub-questions. Then, the questionnaire was piloted with six students who were juniors. They were also asked to evaluate the items after they filled out the questionnaire. Their comments about the questions were reflected on the questionnaire (provided in appendix).

The first three questions aimed at revealing the pre-service science teachers' general knowledge about earthquake. These questions were about the causes, the magnitude and the intensity, and the frequency of an earthquake. The following two questions were about research studies of earthquake conducted by geologists and seismologists. These questions aimed at eliciting the pre-service science teachers' knowledge about the estimation of time and location of an earthquake and about scientific process applied by scientists in earthquake estimation. The last three questions were about pseudoscientific issues related to earthquake. These questions also consisted of sub-questions. In these questions, pseudoscientific issues such as relationship between occurrence of an earthquake and solar eclipse, and appearance of stars, and precursor of an earthquake were used. For instance, one of the questions asked first if they believe that earthquake occurs after solar eclipse. Then, they were asked how they convince other people who were not agree with his/her idea about above statement. Later, they were also asked that what they should do in order to convince scientists to accept his/her ideas as scientific. In another question, pseudoscientific belief that animals such as dogs, birds, ants are the precursor of earthquake was questioned. In this question, we asked how they would scientifically test their ideas about animals being messengers of earthquake. The aim of such questions was to understand what pre-service science teachers knew about these pseudoscientific issues, how they judged the scientific status of these pseudoscientific beliefs, and how they could have proposed research designs to test their own ideas.

Interviews

A total of six pre-service teachers were randomly selected for interviews to validate the questionnaire (Lederman and O'Malley 1990). The interviews were conducted by the first researcher. All the interviews were audio-taped and transcribed verbatim. Data obtained from interviews were not combined with the questionnaire data. These data were used to control the interpretations of the researcher by checking additional evidence from their interviews before making a conclusion.

Data Analysis

A qualitative methodology was applied in data analysis. The questionnaire data were analyzed by applying interpretative analysis (LeCompte, Preissle, & Tesch, 1993). Bottom-up approach was used to constitute categories from the data. In the analysis process, questionnaire responses were first entered into qualitative research software called NVivo. The software enables the researchers to organize and coding their data without any loses in data. Each response was read separately in order to understand pre-service science teachers' views in a holistic perspective. The qualitative data were organized into three main categories. These categories were labelled as "general knowledge about earthquake", "beliefs about earthquake" and "inferences about pre-service science teachers' understanding of science". In the bottom-up process of analysis, the data were coded into these main categories. This process continued until all related data were organized. After coding and categorizing process, coding schemes were modelled for easy understanding of the organization of the data. In qualitative study, the researcher bias is one of the most important treat to the trustworthiness. In the coding process, first researcher coded the data and other researcher who were expert in science education and experienced in qualitative research checked the coded data in order to decrease the researcher bias to minimum and then they resolved the discrepancies by discussing and reaching a consensus.

Results

Pre-service Science Teachers' General Knowledge about Earthquake

The results of pre-service science teachers' knowledge about earthquake included their general knowledge about the causes of an earthquake, the magnitude and intensity of an earthquake, and the frequency of an earthquake. Although holistic perspective was used in the analysis, pre-service science teachers' knowledge about earthquake was generally demonstrated in responses to the first three items of the questionnaire. Thus, their responses were divided into three subcategories; the causes of an earthquake, the frequency of an earthquake, and the size of an earthquake. Pre-service science teachers' knowledge about earthquake was modelled as in Figure 1.

Causes of an Earthquake

The pre-service science teachers' knowledge about causes of an earthquake was coded into two subcategories; the main causes and the relative or alternative causes. The first order causes such as epirogenic and orogenic tectonic movements were coded as the main causes and the others were coded as relative causes. Half of the pre-service science teachers (21) were aware of the plate tectonics which was the theory explaining occurrence of earthquake best. They stated that plates moved around with respect to one another and the boundaries of the plates triggered each other. Five pre-service science teachers mentioned other well-known cause of earthquake, volcanic eruption. Other causes proposed by the pre-service science teachers included faults, accumulation of energy, gas pressure, and climate. Thirteen pre-service science teachers expressed faults as being the main cause of earthquakes. Actually, faults within the Earth's crust result from the action of plate tectonic forces. Exemplifying quotation of pre-service science teacher who mentioned plate tectonics movements was given below;

Gözde: Earthquake resulted from movement of the plates on Earth's crust and interaction between continental and oceanic crust. It is explained by plate-tectonic theory. I mean earthquakes occur as a result of breaks in Earth's crust and movement of continents. Movements on subduction zones activates the Earth’s crust and therefore earthquake occurs.

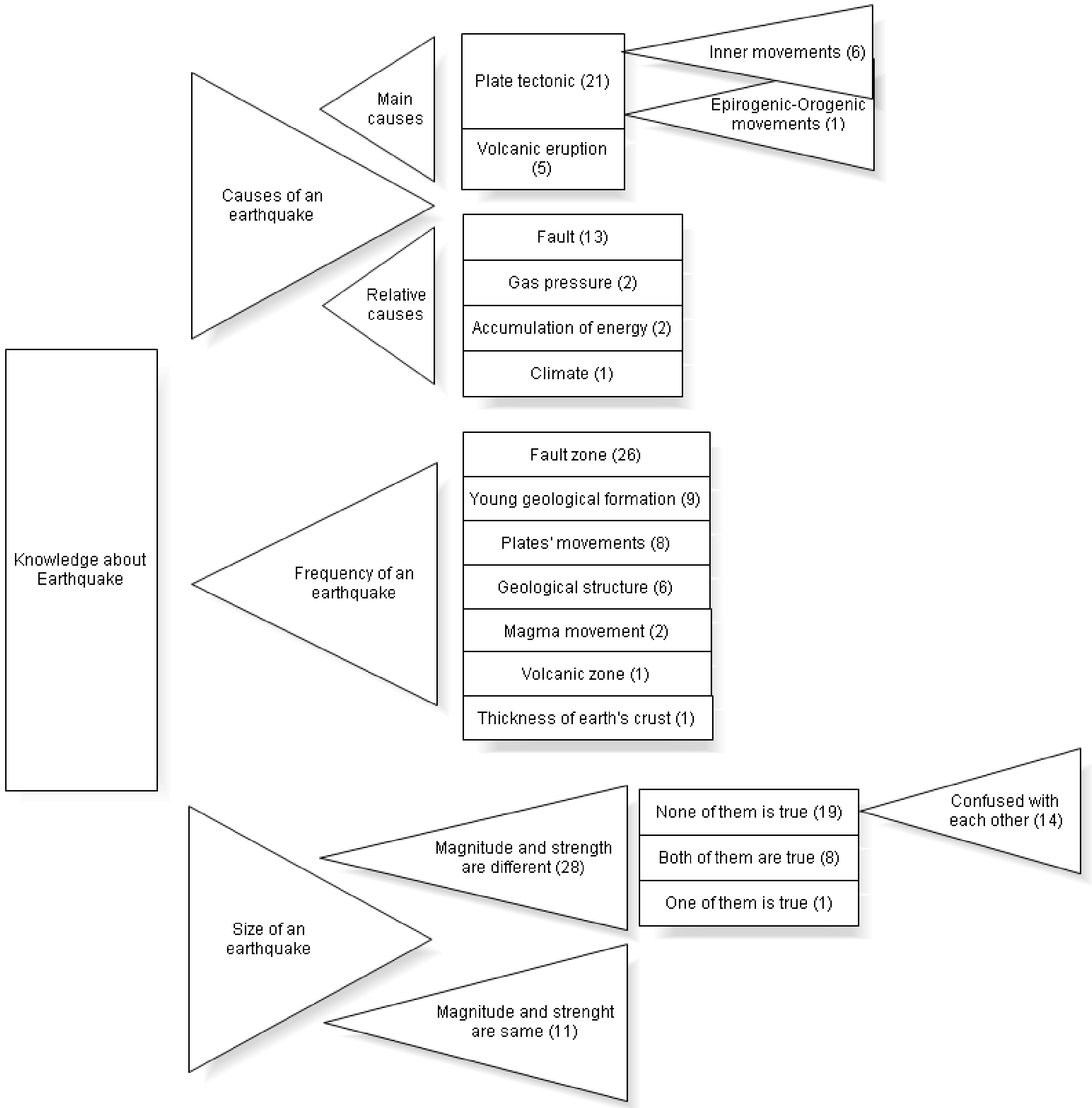

Figure 1. Model of the pre-service science teachers’ knowledge about earthquake

Frequency of an Earthquake

When it was asked that “what are the reasons of occurrence of earthquake more frequently in some areas”, the most frequently given reason was the being on the fault zone. According to twenty-six pre-service science teachers, regions within the fault zone experience more frequent earthquakes than other regions do. The second more frequent reason provided by pre-service science teachers was young geological formation. Nine pre-service science teachers expressed that in the region which had been formed later in the earth’s history like Turkey region, earthquakes occur more frequently in comparison to elder regions. Two quotations were as follows;

> Özlem: Earthquake occurs frequently as a result of one of several possibilities; being located in fault zone, having young geological formation, being located in north hemisphere, and being located in continental margin.

> Ali: Since our country is geologically young country, earthquakes occur frequently in our country. That earthquakes occur less frequently in some areas shows that these areas were geologically formed in earlier in geologic time scale of earth. Additionally there are two fault lines as KAF (North Anatolian Fault) and DAF (East Anatolian Fault). The areas located in these fault zones are geologically more active than others and experience earthquake frequently.

Size of an Earthquake

Magnitude and intensity measure different characteristics of earthquakes. Earthquake magnitude is a measure of the amount of energy released at the source of the earthquake (Buğdaycı, 1999). Earthquake magnitude is recorded by seismographs and is measured by Richter Scale. Earthquake magnitude is quantitative and expressed as an exact number (Wald & Shindle, 2004). On the other hand, earthquake intensity measures the strength of shaking produced by the earthquake at a certain location. Earthquake intensity refers the effects of an earthquake on people, buildings, and natural environment. For that reason, intensity is qualitative and more subjective, and it is expressed as a Roman numeral according to Mercalli Intensity Scale (Wald & Shindle, 2004). The pre-service science teachers were asked what were the magnitude and intensity of an earthquake in the second question. Result indicated that except eight pre-service science teachers, most of them had misconception about the magnitude and intensity of an earthquake. Eleven of them stated that the magnitude and the intensity of an earthquake were the same, while fourteen of them confused the magnitude with the intensity of an earthquake. Related quotation representing the pre-service science teacher who thought that the magnitude and the intensity of an earthquake were the same was given below;

> Kutay: The magnitude and intensity of an earthquake have the same meaning. It means numerical representation of earthquake data. It is measured by seismograph. When the magnitude of an earthquake I mean intensity is calculated, earthquake's epicenter can be determined by using overlap of primer and seconder waves coming from at least three districts.

The pre-service science teachers who were in confusion generally stated that while the magnitude of an earthquake referred to its impacts such as loss of life and property, the intensity of an earthquake is a numerical value measured by Richter scale. Representing quotation was as follows;

> Arzu: The magnitude of an earthquake is the effect caused by an earthquake on the natural environment and on people. For instance, loss of life and property, damage on people and country. On the other hand, the intensity of an earthquake is the numerical value of shaking. For instance, 7.1. I mean it is measurable value.

Pre-service Science Teachers' Beliefs about Earthquake

The pre-service science teachers' beliefs about earthquake are demonstrated in responses to the last three questions. Pre-service science teachers' beliefs about earthquake were modeled as in Figure 2.

Pre-service Science Teachers' Beliefs about Relationships between Occurrence of an Earthquake and Solar Eclipse

It is believed in society that the total solar eclipse is a sign of bad things such as flooding and earthquake. In parallel to this view, believing that the total solar eclipse is followed by devastating earthquake is very common in society. For this reason, the pre-service science teachers' views about this pseudoscientific belief were questioned. The results showed that majority of the pre-service science teachers (33) thought that it was not possible that there was a relationship between experiencing an earthquake just after a solar eclipse. As these pre-service science teachers did not believe in such a so-called relationship propagated by media, it could be concluded that these pre-service science teachers had scientific beliefs about these two phenomena. However, they didn't propose satisfying reasons to explain why they think so in a scientific way. Most of them (19) expressed that earthquake and solar eclipse were independent from each other. The pre-service science teachers also stated that while earthquake occurs on the earth crust, solar eclipse occurs far from the earth; so that these two phenomena should not have any impact on each other. A quotation representing a pre-service science teacher who thought that earthquake and solar eclipse were independent phenomena, for that reason there was no relationship between occurrence of an earthquake and solar eclipse.

> Bengü: The earthquake on August 17, in 1999 in Turkey had occurred six days later the solar eclipse. But in later earthquake on November 12 in the same year, we didn't see any solar eclipse. Thus, I don't think that earthquake and solar eclipse are related to each other. If so, each solar eclipse should be followed by devastating earthquake.

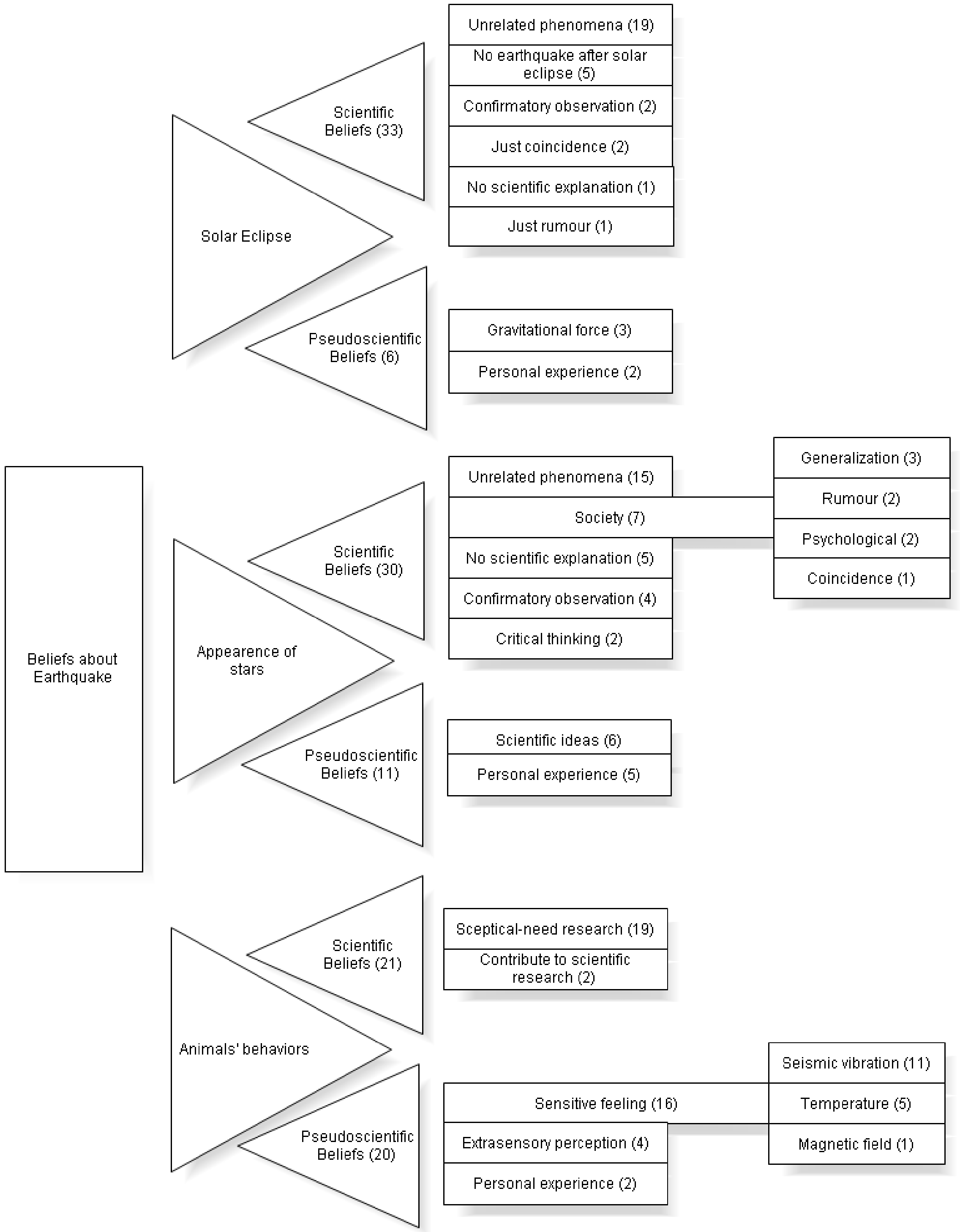

Figure 2. Model of the pre-service science teachers' beliefs about earthquake

A few pre-service science teachers (2) indicated that there was a need of confirmatory observation to explain this observation better and one of them reasoned not believing in this relationship by stating that it was just a rumor originated from the society. These reasons indicated that majority of the pre-service science teachers were not able to consider availability of scientific data or evidence when they judge the status of so-called relationships between occurrence of earthquake and solar eclipse. Only one pre-service science teacher stated that s/he didn't think there was a relationship between them due to the absence of scientific evidence about this issue. Exemplifying quotation of pre-service science teacher who questioned the availability of scientific explanation was given below;

> Mehmet: I don't think so. I think that there is no connection found between solar eclipse and an earthquake. There is no scientific evidence about it. There is no scientific explanation which shows that these are related. The eclipse resulted from rotation of the earth around its own axis. Earthquake is related shaking and breaking of earth's crust, though.

On the other hand, six pre-service science teachers had pseudoscientific beliefs about the relationships between occurrence of earthquake and solar eclipse. They believed that there was certain relationship between occurrence of earthquake and solar eclipse so that total solar eclipse was followed by devastating earthquake. Some of them (3) made explanation by using scientific terms in order to support their beliefs in so-called relationship. They asserted the reason that the gravitational force between earth and sun might trigger the fault line in the earth. Representing quotation was as follows;

> Burak: I know that there is interaction between sun and planets such as gravitational force. During solar eclipse, this force would increase I mean the gravity between sun and earth would increase. The Marmara earthquake in 17 August 1999 occurred just after a total solar eclipse. Thus, it is quite possible that the Marmara earthquake would result from this gravity between sun and earth. The gravity can activate the faults.

As it was seen, this explanation was generally based on naive conceptualization of scientific knowledge. In solar eclipse, the moon is between the earth and the sun so that sun is blocked by the moon. It is impossible that the gravitational force between earth and sun increases. Other reasons were connected to the pre-service science teachers' personal experiences related the solar eclipse and following earthquake occurred in 1999 in Turkey. Related quotation was given below;

> Duygu: The August 17th earthquake occurred after the solar eclipse. I experienced this. This situation might be resulted from the gravitational force between earth and sun. I saw both the solar eclipse and following earthquake. Thus, I can explain people that this isn't a coincidence.

Pre-service Science Teachers' Beliefs about Relationships between Occurrence of Earthquake and Appearance of Stars

There is a common sense in the society that after earthquake, stars shined more brilliantly as if they were closer to the earth. The main reason for this observation was electricity power cut after earthquake. Majority of the pre-service science teachers (30) thought that there was no relationship between the occurrence of earthquake and appearance of stars. As they did not believe in such a so-called relationship and used their rational thinking, they were classified into scientific belief group. However, the majority of them (15) who conveyed scientific beliefs about the relationship between the occurrence of earthquake and appearance of stars just stated that these were two unrelated phenomenon without proposing any scientific explanation. Positively, five of them explained their reasons by considering scientific process. They reasoned that in order to accept this so-called relationship, it has to be a scientific basis and it has to be searched using scientific process. Some of them employed empirical aspect of NOS regarding that there was no scientific data or scientific evidence which support this pseudoscientific relationship between the occurrence of earthquake and appearance of stars. Representing quotation was as follows;

> Gül: I don't think that these are related to each other, because this relationship is not based on scientific data. This belief derives from a rumor that is common in the society.

Furthermore, only two pre-service science teachers made detailed explanation which indicated that they were able to think critically. They stated that this common observation that stars shined brilliantly after earthquake derived from the electricity cutting out which occurred after the brutal earthquake. They also exemplified their opinions by mentioning about rural areas in which less artificial lighting systems were used. Exemplifying quotation was given below;

> Hasan: No, I don't think so. Because of the electricity cutting off after an earthquake artificial lighting systems broke down. Due to the darkness occurred after the earthquake, people feel that stars are more brilliant. Similarly in a village in which there are less artificial lighting systems than urban cities, stars are seen more brilliant.

Additionally, four pre-service science teachers expressed that it wasn't enough to observe the brilliant shining stars only one time just after earthquake. They stated that in order to explain the asserted relationship between the occurrence of earthquake and appearance of stars, it had to be more earthquakes followed by the anomalous appearance of stars. This could be concluded that these pre-service science teachers tended to find more confirmatory data rather than to investigate the events in a more comprehensive manner, which indicated the less understanding of empirical aspect of NOS. Other reasons provided by pre-service science teachers were that they are over-generalization of the observation and rumor generated by the society. Additionally two pre-service science teachers mentioned the role of the people's psychologies in the society. They stated that this was just a psychological issue, because in such circumstances like earthquake or other natural disasters people attempted to make sense of the disaster. Thus, so-called belief about appearance of stars was just a product of people's meaning making attempt. Representing quotation was as follows;

> Serkan: I don't think that these are related to each other. Seeing stars brilliantly might be psychological. Under such circumstances, people attempt to make sense of the cause of these natural disasters that they could not understand exactly. The belief related to the brilliant appearance of stars is a conclusion of such a process.

On the other hand, one fourth of the pre-service science teachers (11) conveyed pseudoscientific beliefs about the relationship between the occurrence of earthquake and appearance of stars. They believed that stars shined more brilliantly just after devastating earthquake. The pre-service science teachers who conveyed pseudoscientific beliefs about the relationship between the occurrence of earthquake and appearance of stars generally used scientific terms when they reasoned out their beliefs. These are the reflection of the lights based on magma migration or the gas extraction. However, these ideas didn't reflect the profound scientific understanding of these scientific terms. Five of them explained their opinions by stating their personal experiences related to the brilliant shining stars after earthquake. Representing quotation was given below;

> Ahmet: In the Marmara earthquake, when I looked at the sky, I saw the stars more clearly and more brilliant than they had ever before. But, I don't know the reason for this. But I felt that the stars were very close to the earth as if they were able to be reached. They should be related.

These pseudoscientific beliefs of the pre-service science teachers are indicator of the naïve views about the difference between observation and inference aspect of NOS. These pre-service science teachers weren't able to infer the underlying cause of the observation of brilliant stars. Although they stated that they didn't know the reason for this situation, they just believed in this relationship since they experienced it. Similar to the pre-service science teachers looking for more confirmatory observation, these pre-service science teachers stating their personal experiences had well-known misconception of seeing is knowing (Khishfe, 2008), since for these pre-service science teachers, it was enough to see something in order to believe in it without employing inferential scientific process to generate scientific knowledge. Interestingly one of them who believed in this pseudoscientific relationship indicated another pseudoscientific belief that the brilliant appearance of the stars and the number of stars visible in the sky would be indicators of the coming earthquake. Because the appearance of stars is important sign for the society not only just after earthquake, but also before earthquake. Related quotation was as follows;

> Nevin: When I was a child, my mother taught me that if the weather was very clear and there were lots of stars, it indicated not only that it might be a earthquake, but also that the weather would be good. I believed in what my mother said and I have still believed in it.

Pre-service Science Teachers' Beliefs about Animals' Behaviors as a Predictor of Earthquake

The notion that animals can sense earthquakes before they occur has been discussed both in the society and in the scientific community. Because of being unpredictable, geoscientists have no way of knowing exactly when or where the next earthquake will hit. Because large earthquakes associated with a particular fault are infrequent, geoscientists are forced to hypothesize earthquake precursors such as animal behavior. However, none of these have resulted in total success (NSTA, 2007). Additionally, Cicerone, Ebel, and Britton (2009) defined some earthquake precursors. These are electric and magnetic fields, gas emission, water level change, temperature change, surface deformations, and seismicity. Although there were anecdotal reports of unusual animal behaviors, they did not classify these animal behaviors as earthquake precursor and stated that these anecdotal reports have not been documented scientifically in a quantitative way. Remarkable evidence about unusual animal behaviors came from Kirschvink (2000). He mentioned theory of tectonic plate and based on this theory he gave an explanation of unusual animal behaviors. According to plate tectonic, there are two types of seismic wave that are p-wave and s-wave. P-wave or primary wave is the first wave to arrive to the crust and is a non-destructive wave. On the other hand, it is followed by s-wave or secondary wave. It is a destructive wave and travels slower through the Earth's crust than the non-destructive p-wave do. According to him, this delay between the arrival of the p-wave and destructive s-wave could provide enough of a warning to trigger a death-avoiding response immediately prior to the arrival of the more damaging s-waves, if animals are sensitive enough to detect p-wave before s-wave.

In contrast to other two pseudoscientific situations, more pre-service science teachers believed that earthquake might be predicted by observing the behaviors of animals. Half of the pre-service science teachers (20) conveyed pseudoscientific beliefs about this issue. The majority of them (16) stated that animals had sensitive feelings. They stated that animals feel seismic vibration of earth’s crust, increased temperature of earth crust, and the earth’s magnetic field. Two representing quotations were given below;

> Serpil: I think that some animals can feel seismic vibration of earth’s crust much more strongly and earlier than people do. It might have scientific bases. When we consider the behaviors of these animals before earthquake, it reveals that their senses are much more advanced than ours. This is a scientific knowledge.

> Suat: It is known that before earthquake, the temperature of the earth’s crust increases. For this reason, creatures go up to the surface. This behavior of animals is precursor of earthquake. Measuring the temperature of the earth’s crust before and during an earthquake and correlating them with behavior of animals would provide scientific bases for this.

Interestingly, four pre-service science teachers who had pseudoscientific beliefs reasoned their beliefs that animals had extrasensory perception. One quotation of them was as follows;

> Osman: I can say that it derives from the extrasensory perception that is peculiar to animals. If the same situation is observed in the every earthquake circumstance, it might be understood that this isn’t a coincidence, it is real.

Believing in extrasensory perception is considered as pseudoscientific belief (Martin, 1994). Thus, having ideas about extrasensory perception showed that these pre-service science teachers additionally had another pseudoscientific belief.

The half of the pre-service science teachers (21) had scientific belief about so-called animals’ behaviors as a predictor of earthquake. Although these pre-service science teachers stated that such animal behaviors would be indicator of approaching earthquake, it had to be searched scientifically in order to be accepted as scientific. It can be assumed that these pre-service science teachers were aware of the underlying assumption of science and they are also aware of that a claim can be accepted as scientific if it’s supported by scientific data.

Inferences about Pre-service science Teachers’ Understanding of Science

Pre-service science teachers’ responses to the last four questions revealed additional information about their understandings of science. These questions with their sub-questions revealed pre-service science teachers’ knowledge about how geoscientists work, how scientific knowledge is generated, and what characteristics should scientific knowledge have. Pre-service science teachers’ understandings of science were modelled as in Figure 3.

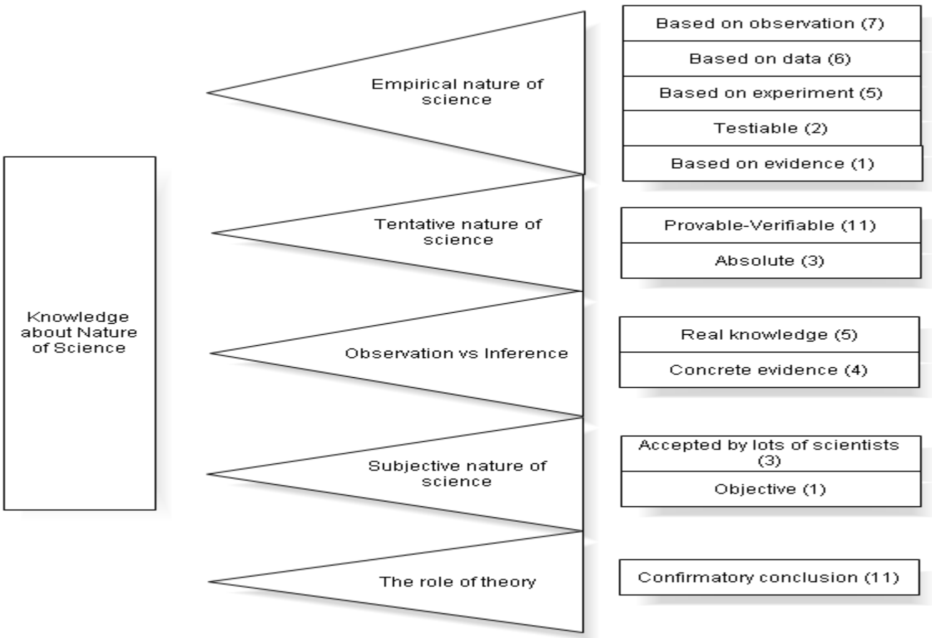

Figure 3. Model of the pre-service science teachers' knowledge about NOS

Pre-service science teachers' responses to the last four questions reflected their own understandings about empirical aspect of NOS, tentative aspect of NOS, subjective aspect of NOS, difference between observation and inference, and the role of theory in science. In some aspects of nature of science, the pre-service science teachers had informed understanding of science, but in some aspects they reflected naive understanding of science.

Making observation and experiment, testing something and collecting data and evidence are very important processes in generating scientific knowledge. Positively, fifteen pre-service science teachers stated these processes while they were explaining their ideas. For instance, for the empirical nature of science, some pre-service science teachers thought that to be accepted as scientific by other scientists and geologists, a research study should be conducted by using scientific methods such as observation and experiment, thus it should be based on scientific data and evidence. Representing quotation was as follows;

> Erdem: Earthquake depends on strain energy accumulation in faults. The information about earthquake could be obtained by using data collected from those faults. But scientific data and evidence should be used in this type of research. I mean, I must be based on observation and experiment. The research must be based on scientific processes. It is impossible to say that occurrence of earthquake and solar eclipse are related unless your research is based on scientific way.

According to nature of science literature, scientific knowledge is subject to change (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002; Schwartz, Lederman & Crawford, 2004). About tentative nature of science, eleven pre-service science teachers stated that scientific knowledge had to be provable or verifiable and three pre-service science teachers thought that scientific knowledge is absolute. Exemplifying quotation was as follows;

> Damla: I don't think that there is a relationship between brightness of stars and occurrence of earthquake, because there is no scientifically proven knowledge about this issue. To accept knowledge as scientific, it should be tested and proved by experiments. If scientists conduct researches to understand where these thoughts (common in public) stem from, they would handle it scientifically and they would get proven scientific knowledge. By this way, this knowledge becomes certain knowledge.

This type of views of pre-service science teachers indicated naïve understanding of tentative NOS. Thereby, pre-service science teachers who stated that scientific knowledge had to be provable or verifiable and absolute were unable to comprehend one of the most important aspects of science which assures the advancement of science and paves the way for new and more research.

Another most stated notion by pre-service science teachers was necessity of the confirmatory conclusion. Eleven pre-service science teachers stated that if any event occurs as routine in the every earthquake, this indicates that there is a relationship between earthquake and that event. For these pre-service science teachers, just observing ants going up to the surface just before an earthquake is an evidence showing the relationship between the occurrence of earthquake and animal behaviors. Representing quotation was given below;

> Selami: To make scientific research, first of all you need to know where earthquake will hit again. But, it is impossible. For this reason, it is hard to make scientific research about it. If I want to conduct scientific research, I would choose a district where the earthquake occurs frequently. For example Japan. Then I would collect supportive data consistently which shows that animals move to earth's surface prior to earthquakes. If I observe that animals abandon their homes prior to each earthquake, it is an evidence for that animals can sense earthquakes better than we do.

However, correlation does not prove causation. Science and pseudoscience use different processes to generate knowledge. In scientific process, many facts are observed, data are collected from different sources, and evidences are found in the data and used to draw conclusions. Conversely, in the pseudoscientific process, conclusion is drawn at the beginning of the process, and then related facts are found to support this conclusion disregarding irrelevant ones. Additionally, confirmatory observation views provided by pre-service science teachers indicated that they didn't realize the important role of theories in science. Theories intend to explain natural phenomenon by using different data sources which might support or may not support the explanation. Thus, theories intend to make comprehensive explanation not only using supporting data, but also including abnormal variation in data. Adversely, pseudoscientific explanations intend to use only supporting data to convince people in that explanation and intend to ignore unsupported data. Therefore, pre-service science teachers looking for only confirmatory data or conclusion had naïve understanding of underlying attributions of science and its theories.

Similar to the misunderstanding of the role of theories or scientific process, some pre-service science teachers were also unable to articulate the difference between observation and inference. Nine pre-service science teachers needed concrete or visual evidence or knowledge in order to explain or test their ideas. For instance, in order to test their ideas about the relationship between earthquake and the animal behaviors, five of them proposed research design in which animal behaviors are observed by just using video camera only one time. For these pre-service science teachers, it is enough to observe only one time as this observation would be recorded by video camera. Additionally, they referred this type of data as real knowledge. In other examples, four pre-service science teacher stated that in order to convince people or scientists about his/her claim that there was a relationship between the occurrence of earthquake and solar eclipse, they would display videos or photographs provided by the Internet and official documents related to earthquake occurred six days after the total solar eclipse in 1999. For these pre-service science teachers it was enough to see concrete materials in order to believe something or it was enough to display concrete materials in order to convince people to believe in an idea which they defended. Thus, these pre-service science teachers weren't aware of the inferential process used in science in order to find the reasons of observations and to draw a scientific conclusion. One quotation of them was provided below;

> Cansu: During the earthquake in 1999 I saw that the stars were brighter and closer to us than usual. Sun went down earlier. I was aware of that something was going wrong. I experienced the earthquake in 1999, so I can explain to people that a total solar eclipse occurred just a few days before the devastating earthquake. I can tell them it was not a coincidence. I can talk about that day according to my personal observation. I can show them the photos I took that day. Because, it was incredibly different. It is impossible to realize that from the photos. I can support by showing formal records, photos, and video records about that day. Therefore, I can explain the relationship between solar eclipse and earthquake scientifically by using such scientific sources.

Additionally, three pre-service science teachers stated that in order to accept an idea as scientific, it needed to be accepted by lots of scientists or people. One of them stated that in order to test her idea about the relationship between earthquake and animal behaviors, she would ask people who experienced the earthquake and would survey their observations about abnormal behaviors of animals; thereby she would draw a conclusion if more people stated this observation. Similarly, one pre-service science teacher thought that science had to be objective. These thoughts of pre-service science teachers might indicate that the majority's opinion had a priority for them, and thus scientific knowledge had to be universal. Therefore, it could be said that these pre-service science teachers had naïve understanding about the subjective NOS and socio-cultural impact on science.

Discussion

In this study, mainly pre-service science teachers' scientific and pseudoscientific beliefs about earthquake were evaluated. The results of this study showed that pre-service science teachers knew some basic principles of earthquakes. Most of them were aware of the plate tectonics as the main cause of earthquakes. Some of them were also aware of volcanic eruptions would also cause earthquakes. Moreover, they knew that frequency of earthquakes depend on fault zones, young geological formations, and movements of plates. However, they had misconception about magnitude and intensity of an earthquake.

Regarding pre-service science teachers' beliefs about earthquakes, majority of the pre-service science teachers did not have pseudoscientific beliefs about the relationship between occurrence of earthquakes and occurrence of solar eclipse. Similarly, whilst most of the pre-service science teachers conveyed scientific beliefs stating that there was no relationship between earthquakes and appearance of stars, only one of forth of them conveyed pseudoscientific beliefs. However, in the context of animals' behaviors as predictor of earthquake, more pre-service science teachers conveyed pseudoscientific beliefs. Although most of the pre-service science teachers did not believe these types of pseudoscientific relationships, they didn't propose satisfying reasons to explain their ideas.

Furthermore, the pre-service science teachers' understandings about science were also elicited indirectly through their knowledge and beliefs about earthquake. The pre-service science teachers indicated views about empirical, tentative, subjective NOS, the difference between observation and inference, and the role of theory in science. Although they reflected adequate views about empirical NOS, they indicated inadequate views about other aspects of NOS.

According to results, it was apparent that although pre-service science teachers had scientific knowledge about the causes and frequency of an earthquake, they had pseudoscientific beliefs and inadequate understanding about science in this context. Reason for this contradictory situation may be related to the lack of connection between subject matter knowledge and aspects of NOS. Therefore, the pre-service science teachers would have difficulties to transfer their understanding about science into subject matter knowledge or everyday contexts. Likewise, Afonso and Gilbert (2010) reported similar result indicating that university students had inadequate views about NOS in the context of water dowsing because of the lack of epistemological course in which they could engage explicitly with NOS and the existence of difficulties in transferring concepts of NOS from formal education to everyday contexts. Although the pre-service science teachers participated in this study had courses related to both nature and history of science, and geology, this contradictory situation might be resulted from teaching style of these courses. Generally NOS was taught by using de-contextualized NOS activities such as black-box and cubes activities (Lederman and Abd-El-Khalick, 1998). Clough (2006) suggested using both de-contextualized and contextualized explicit NOS activities as an effective way of teaching NOS. More effective nature and history of science courses in which students could engage in both de-contextualized and contextualized activities would be designed. Therefore, it might be prevented the over-simplification of teaching NOS by using only de-contextualized NOS activities which cannot provide opportunity to make connection between aspects of NOS and everyday contexts or subject matters of science, and it might provide opportunity in which students might conceptualize NOS effectively in a more scientific and meaningful context. Using some pseudoscientific beliefs about earthquake in geology course and discussing these beliefs in a more scientific perspective might be more meaningful for students in demarcation of science from pseudoscience and in understanding NOS itself.

It was interesting that more pre-service science teachers conveyed pseudoscientific beliefs about animals' behaviours as predictor of earthquake compared with the other pseudoscientific relationships of earthquake. It might be linked to its bias and underpinning propagation in popular media. Prediction of earthquake by using animals' behaviours was more-discussed pseudoscientific subject than solar eclipse and appearance of stars subjects did. Preece and Baxter (2000) supported this idea stating that the popular media provided a stream of ill-informed and uncritical material that helped to establish and reinforce superstitious and pseudoscientific beliefs among adults and children. Martin (1994) indicated basic methodological difference between science and pseudoscience stating that science critically tests its theories and hypotheses and modifies them in the light of the evidence whereas pseudoscience doesn't. For years, geoscientists have been trying to hypothesize earthquake precursors such as animals' behaviours. Nevertheless, these attempts have not yielded scientific results which indicate animals change their behaviours specifically prior to earthquakes.

In this study, it was revealed that some of the pre-service science teachers had knowledge about empirical aspect of NOS. They were aware of that scientific knowledge had to be based on observation, experiment, data, and evidence. However, Erduran (1995) expressed that the description of scientific method in a way that it consists of gathering data, formulating hypothesis to explain the data and testing the hypothesis by experiment wasn't sufficient to distinguish science from pseudoscience. Although the pre-service science teachers were aware of the scientific process, they had difficulties to demarcate science from pseudoscience in earthquake context. They also had some misconceptions about other aspects of NOS, especially tentative NOS. They thought that scientific knowledge has to be proved and absolute. Erduran (1995) stated that progression of science was one of the most important demarcation criteria of science from pseudoscience. Progressions in science are provided by constructing scientific theories for explanations of natural phenomena. Understanding the role of the theories in science is related to understanding of other aspects of NOS. For instance, accepting a scientific knowledge or theory as absolute constitute one of the most important obstacles for progression of science.

Actually, these types of views of the pre-service science teachers were based on their views about direct observation and confirmatory conclusion. They weren't aware of the inferential process; rather they based their ideas only on direct observation. For instance, many pre-service science teachers thought that if some earthquake were followed by the anomalous appearance of stars, it was concluded that there was a relationship between occurrence of an earthquake and appearance of stars. These results showed that these pre-service science teachers were interested in only selective use of data rather than considering the quality or validity of data. This tendency of the pre-service science teachers was stated by Radner and Radner (1982) in their study related to marks of pseudoscience. They expressed that pseudoscientists were generally interested in volumes and quantity of evidence and they tended to use selective data which confirm their ideas. Pseudoscientists might also have tendency to use personal experience and anecdotes as evidence and might have tendency to use eyewitness evidence. Similarly, in this study, for some pre-service science teachers in order to believe in something without employing inferential scientific process to generate scientific knowledge, it was enough to see something or hear about it to be seen by another person. Additionally, their research designs in which they just observe animal behaviours or stars might support this tendency of the pre-service science teachers. Thus, they stated that visual records were enough to prove whether there was a relationship or not.

Understanding NOS is seen as a critical component of science literacy. Science literacy also requires having scientific and critical thinking skill. Demarcation of science from pseudoscience has close relationship with being critical thinker. Critical thinkers are supposed to be able to recognize the difference between science and pseudoscience, and realize and appreciate the scientific methods used in formulation of hypotheses and in construction of scientific theory. Unfortunately, since they didn't propose adequate reasoning while they explain their ideas, it was obvious that the pre-service science teachers, whether believe or not in pseudoscientific ideas, weren't able to evaluate the ideas which they encountered by using their critical thinking skills.

Conclusion

According to the research results, it could be concluded that some pre-service science teachers had pseudoscientific beliefs about earthquake contexts, although they had science education. Additionally, rest of the pre-service science teachers weren't able to reason out their ideas scientifically and to propose scientific explanation about why they didn't believe in pseudoscience, although they didn't convey pseudoscientific beliefs. Although they had courses both about NOS and geology, they had difficulties in integrating their knowledge about both contexts. It might be resulted from unintegrated teaching of NOS. It's taught as a separate course, and generally ignored in other courses. Thus, the pre-service science teachers were not able to articulate their knowledge learned in NOS course when they reason about pseudoscientific beliefs about earthquake. Therefore, it would be recommended that understanding of NOS and conceptualizing demarcation criteria between science and pseudoscience should be intended to be developed within the subject matter of science and it should be integrated into other courses by explicitly emphasizing in real science contexts.

It's obvious that some pre-service science teachers had difficulties to in integrating their NOS understanding into subject matter knowledge or everyday contexts. This lack of understanding and integration can be potentially harmful to their in-service teaching experiences. Naturally, teachers cannot be assumed to teach what they don't know and don't understand effectively.

References

Afonso, A.S., & Gilbert, J.K. (2010). Pseudo-science: a meaningful context for assessing nature of science. *International Journal of Science Education, 32(3),* 329-348.

Aksoy, Shridan, R.A. (2007). Kentte mitsel korku: "Fısıltı" Depremleri (Mythical Fear in Urban: Whisper Earthquakes). *Millî Folklor, 19*(75), 126-133.

Barnes,A., Abd-EI-Fattah, S., Chandler, M., & Yates, G.C.R. (2008). New age beliefs among teacher education students. *Critical & Creative Thinking, 16*(2), 23-37.

Buğdaycı, İ. (1999). Depremin dili: Sismoloji. *Bilim ve Teknik Dergisi*, 382 (Eylül), 26-30. Retrieved from http://www.biltek.tubitak.gov.tr/sandik/deprem/sismoloji2.html.

Castelao-Lawless, T. (2002). Epistemology of science, science literacy, and the demarcation criterion: the nature of science (NOS) and informing science (IS) in context. Paper Presented at the Informing Science & IT Education Joint Conference: InSITE 'Where Parallels Intersect', Cork, Ireland.

Cicerone R.D., Ebel J.E., Britton J. (2009). A systematic compilation of earthquake precursors. *Tectonophysics, 476*(3-4), 371-396.

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: considerations for effective nature of science instruction. *Science & Education, 15,* 463-494.

Çağatay, İ. H. (2005). Failure of an industrial building during a recent earthquake in Turkey. *Engineering Failure Analysis, 12,* 497-507.

DeRobertis, M. M., & Delaney, P. A. (2000). A second survey of the attitudes of university students to Astrology and Astronomy. *Journal of the Royal Astronomical Society of Canada, 94,* 112-122.

Erduran, S. (1995). *Science or pseudoscience: does science education demarcate? the case of chemistry and alchemy in teaching.* In F. Finley, D. Allchin, D. Rhees, & S. Fifield (eds), Proceedings of the Third International History, Philosophy and Science Teaching Conference,Vol. *1*, 348–354.

Good, R., & Slezak, P. (2011). Editors' introduction. Science & Education, *20*(5–6), 401–409.

Hurd, P.D. (1998). Scientific literacy: new minds for a changing world. *Science Education*, *82*(3), 407-416.

Johnson, R.M. (2003). *Is knowledge of science associated with higher skepticism of pseudoscientific claim?* University of Tennessee Honors Thesis Projects.

Kallery, M. (2001). Early-years educators' attitudes to science and pseudo-science: the case of astronomy and astrology. *European Journal of Teacher Education*, *24*(3), 329 342.

Khishfe, R. (2008). The development of seventh graders' views of nature of science. *Journal of Research in Science Teaching, 45*(4), 470-496.

Kirschvink, J.L. (2000). Earthquake prediction by animals: evolution and sensory perception. *Bull. Seismological Society of America*, *90*, 312–323.

Kuhn, T.S. (1996). *The structure of scientific revolutions (third edition).* Chicago: The University of Chicago Press.

Lecompte, M. D., Preissle, J., & Tesch, R. (1993). *Ethnography and qualitative design in educational research (2nd Ed).* San Diego: Academic Press.

Lederman, N.G. (2007). *Nature of science: past, present, and future.* In Abell, S. K., Lederman, N. G. (Eds), Handbook of research on science education, pp. 831-879. London, Lawrence Erlbaum Associates.

Lederman, N. G., & Abd-El-Khalick, F., (1998). *Avoiding de-natured science: activities that promote understanding of the nature of science.* In W. McComas (Ed.), The nature of science in science education: Rationales And Strategies, Pp.83-126. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lederman, N.G., Abd-El-Khalick,F., Bell, R.L. & Schwartz, R.S. (2002) Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lederman, N. G., & O'Malley, M. (1990) Students' perceptions of tentativeness in science: development, use, and sources of change. *Science Education, 74,* 2, 225-239.

Losh, S.C. & Nzekwe, B. (2011). Creatures in the classroom: Pre-service science teacher beliefs about fantastic beasts, magic, extraterrestrials, evolution and creationism. *Science & Education*, 20, 473-489.

Lundström, M., & Jakobsson, A. (2009). Students' ideas regarding science and pseudo-science in relation to the human body and health. NORDINA, *5*(1), 3-17.

Martin, M. (1972). *Concepts of science education: a philosophical analysis*, Scott, Foresman, and Co., Chicago, IL.

Martin, M. (1994). Pseudoscience, the paranormal, and science education. *Science & Education, 3,* 357-371.

Merriam, S. B. (2009). Qualitative research. A guide to design and implementation. San Francisco: Jossey-Bass Publishers.

National Science Teachers Association. (2007). *Earthquakes, volcanoes, and tsunamis: resources for environmental literacy.* United States of America.

Popper, K. (1963). *Conjectures and refutations*. New York: Basic Books.

Preece, P.F. W., & Baxter, J.H. (2000). Scepticism and gullibility: the superstitious and pseudo-scientific beliefs of secondary school students. *International Journal of Science Education*, *22*(11), 1147-1156.

Radner, D., & Radner, M. (1982). *Science and unreason*. Belmont, CA: Wadsworth Inc.

Shermer, M. (1997). *Why people believe weird things: pseudoscience, superstition, and other confusions of our time.* New York: W. H. Freeman and Company.

Sugarmann, H., Impey, C., Buxner, S., & Antonellis, J. (2011). Astrology beliefs among undergraduate students. *Astronomy Education Review*, *10*(1). doi: 10.3847/ AER2010040

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

Turgut, H. (2011). The context of demarcation in nature of science teaching: the case of astrology. *Science & Education*, *20*(5-6), 491-515.

Wald, L., & Shindle, W. (2004). Magnitude vs. Intensity. *USGS Science for a Changing World*. Retrieved from http://earthquake.usgs.gov/learn/teachers/Mag_vs_Int_Pkg.pdf

Walker, W.R., Hoekstra, S.J., & Vogl, R.J. (2002). Science education is no guarantee of scepticism. *Skeptic*, *9*(3), 24-29.

Whittle, C.H. (2004). Development of beliefs in paranormal and supernatural phenomena. *Skeptical Inquirer*, *28*(2).

Author Information

Duygu Metin
Abant Izzet Baysal University, Turkey
Contact e-mail: *metin_d@ibu.edu.tr*

Hamide Ertepinar
Istanbul Aydin University, Turkey

Appendix

Questionnaire

1. What are the causes of an earthquake?
2. What are the reasons of occurrence of earthquake more frequently in some areas than others?
3. What are the magnitude and strength of an earthquake? How are the magnitude and strength of an earthquake measured?
4. Is it possible to know the time and location of an earthquake? How?
5. How do geoscientists produce ideas about when and where might an earthquake happen? What do they benefit from to produce ideas about estimation of earthquake?
6. Do you think that there is a relationship between occurrence of an earthquake and solar eclipse?
   - i. If so, explain this relationship?
   - ii. How do you convince other people who do not agree with you to believe in your idea?
   - iii. What criteria your way should have in order to convince scientists to accept your idea and way as scientific?
   - iv. If not, why do you think that?
7. Some observations which stated that in the night of earthquake stars are observed more brighter than ever before were cited by society. Do you think that there is a relationship between occurrence of an earthquake and appearance of stars?
   - i. If so, explain this relationship?
   - ii. If so, how do you test this relationship?
   - iii. What criteria your test should have in order to be accepted as scientific?
   - iv. If not, why do you think that?
8. What do you think that ants leaving their nests or fish swiming near the surface before the earthquake are seen as precursors of an earthquake?
   - i. Do these thoughts have scientific bases? How?
   - ii. If you want to test the claim about messenger animals, how do you design a research?