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# Pseudo-Scientific Beliefs and Knowledge of The Nature of Science in Pre-Service Teachers

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## Abstract

This study aimed to determine the levels of pre-service teachers' nature of science (NOS) knowledge, assess their pseudo-scientific beliefs, and examine the relationship between aspects of their NOS knowledge and these beliefs. It also aimed to determine whether NOS knowledge and pseudo-scientific beliefs depended on the discipline and gender. A survey method was conducted in this study. Data were collected from 215 pre-service teachers who are being educated in different fields in a state university. Two different five-point Likert scales were applied. Scale 1, which has three factors, measured pseudo-scientific beliefs, while Scale 2, which has seven factors, measured NOS knowledge. As a result, pre-service teachers' NOS knowledge was found to be inadequate and their pseudo-scientific beliefs were excessive. All factors of Scale 1 were positively correlated with each other, and they were correlated with some components of NOS knowledge. Significant differences were found between disciplines in the analysis of the factors of Scale 2; however, no significant differences were found between genders.

## Introduction

The nature of science (NOS) is an important component of scientific literacy (Michaels, Shouse, & Schweingruber, 2008; Williams & Rudge, 2019). NOS has thus been a dominant topic within science education (Allchin, 2011; Erduran & Dagher, 2014; Irzik & Nola, 2011). Norris and Phillips (2003) refer to NOS as one of the eleven features that define scientific literacy and claim that it is necessary to "distinguish between what is and what is not science". The NOS is a way of understanding science that includes features such as the experimental nature of scientific knowledge, observation, inference, creativity and imagination, scientific theories and laws, theory-dependency, and sociocultural values (Turgut, 2009). Understanding the NOS gives students the ability to correctly understand and interpret the scientific knowledge that they will be exposed to throughout their lives, and allows them to apply appropriate scientific research principles at all levels and for all purposes. (Lederman & Lederman 2014). If this does not occur, pseudo-science may replace science.

Pseudo-science refers to arguments and theories that are not supported by empirical evidence and violate the known laws of science, but which use scientific language to appear valid science (Shermer, 2002). The importance of raising awareness about the negativity of pseudo-scientific beliefs and the positive effect of the NOS is obvious when making important or life-changing decisions. However, research has shown that the information found in books and the media often contains many misconceptions about the NOS (e.g. Abd-El-Khalick, Waters & Le, 2008; Altındağ, Tunç Şahin & Saka, 2012; Irez, 2008). The media may frequently be responsible for the spread of misconceptions and non-scientific knowledge (Castelão-Lawless, 2002; Shein, Li & Huang, 2014). According to a survey conducted by the PEW Research Center, 42% of American adult people believe spiritual energy can be located in physical objects, 33% believe in reincarnation and 29% believe in astrology (Gecewicz, 2018). Studies have shown that pseudo-scientific ideas, such as beliefs in the existence of aliens, sixth sense, telekinesis, astrology, lucky numbers, ghosts, and telepathy are relatively common (National Science Board, 2006). In the literature, studies examining the relationship between pseudo-science and the NOS have generally used pseudo-science to determine the levels of understanding of the NOS (e.g. Kirman-Çetinkaya & Laçin-Şimşek, 2012; Saka & Sürmeli, 2017; Turgut, Akçay & Irez, 2010; Yardımcı, 2019). These data show that a significant section of society has difficulty distinguishing between scientific and non-scientific thinking. Castelão-Lawless (2002) claims that the critical skills that can distinguish between science and pseudo-science are not taught to individuals in schools.

It has been suggested that teachers may responsible for the inadequacy of the general public's knowledge of the NOS (Aslan, Yalçın & Tasar, 2009; Lederman, 2007). Teachers with naïve opinions about the NOS and how to distinguish between science and pseudo-science will not be able to guide their students properly (Ağlarcı & Kabapınar, 2016). Schwartz et al. (2007, p.23) emphasize that teachers should be aware of the NOS as a part of the science literacy and science program, as well as being aware that students need to be motivated to learn science. Individuals' perceptions of science and scientists are shaped at a young age, and this greatly affects whether they continue to study science in the future and whether they are able to solve the problems they encounter in their daily lives by using the scientific thinking skills (Angın & Özenoğlu, 2019). Teachers believe that it is necessary for students to understand the NOS, but this is generally insufficient (Abd-El-Khalick, 2005). They should also have pedagogical knowledge about how to teach the NOS (Hanuscin, Akerson & Phillipson-Mower, 2006) and be willing to teach it.

The NOS as a topic has been increasingly brought into education in recent years, and both students and teachers have engaged more successfully with it; however, resistance has continued to be met from both groups (Lederman, Bartos, & Lederman, 2014). For example, science teachers usually do not want to spend time teaching the NOS (Williams & Rudge, 2019). Many science teachers think that education about the NOS takes away valuable time from teaching the traditional science content (Clough, 2006). Researchers have queried whether teachers can adequately answer the question "What is science?" and whether the current curriculum and teaching materials support their efforts to teach their students about the NOS (Emran, Spektor-levy, Tal, & Assaraf, 2020).

Teachers, pre-service teachers, students, and academics have similar misconceptions regarding the NOS (Abd El-Khalick, et. al., 2008; Altındağ, et. al., 2012; Irez, 2006). According to research, teachers' knowledge of the NOS is generally inadequate (e.g. Aslan, et. al., 2009; Akerson, Abd-El-Khalick & Lederman, 2000; Erdoğan, 2004; Doğan Bora, 2005). It has also been determined that pre-service teachers believe a number of common myths about the NOS (Doğan Bora, 2005; Köseoğlu, Tümay, Üstün, 2010). Having pseudo-scientific beliefs may be the result of not having enough knowledge about the NOS. On the other hand, these beliefs themselves may hinder the acquisition of knowledge of the NOS, because this knowledge should enable individuals to understand the difference between science and pseudo-science. It should thus be investigated whether there is a relationship between the two domains and whether they are affected by each other.

Despite studies showing that teachers' and pre-service teachers' misconceptions about the NOS are similar, no study has been found on whether the misconceptions about the basic components of the NOS differ. Snow and Collini (2012) argued that modern education systems divide society into the "two cultures" (the natural sciences and the social sciences) and it is important whether there is a difference between these two cultures' views of the NOS. There is a limited number of studies on whether teachers' and pre-service teachers' inadequate knowledge of the NOS differs with regard to the subjects they teach (Gül, 2016; Kızılcık, Temiz, Tan, & Kandil-İngeç, 2007). Because NOS is often associated with science lessons, studies on the NOS and pseudo-science have mostly been conducted with science teachers or pre-service science teachers (e.g. Ağlarcı & Kabapınar, 2016; Arı, 2010; Aslan, 2009; Mesci, 2016; Saraç & Cappellaro, 2015). It should be considered, however, that students interact with elementary school teachers before science teachers (Saraç & Cappellaro, 2015). However, the number of studies on the NOS related to elementary school teachers is limited (e.g. Arı, 2010; Saraç & Cappellaro, 2015; Tatar, Karakuyu, & Tüysüz 2011; Yalçın & Yalçın, 2011). In addition, some studies of pre-service preschool teachers have shown that they had an insufficient understanding of the NOS (e.g. Erdaş Kartal & Ada, 2018; Türk, Yıldırım, Bolat, Ocak İskeleli, 2018; Uçar & Şahin, 2018). Pre-service preschool teachers and elementary school teachers have similar misconceptions to pre-service science teachers with regard to the NOS (Erdaş Kartal & Ada, 2018; Saraç & Cappellaro, 2015). Moreover, there is only a limited number of studies on the NOS knowledge of pre-service art, music, history and social science teachers (e. g. Gürel, 2002, Tufan, 2007; Kızılcık, et. al., 2007).

Although research has shown that teachers' and pre-service teachers' misconceptions about the NOS are similar, some studies have also found that gender plays a role in the types and level of pseudo-scientific beliefs (e.g. Gürgil, 2019; Preece & Baxter, 2000; Sjödin, 2002; Williams, Francis, & Robbins, 2007). Could this be due to those of different genders having different knowledge of the NOS? The question can be asked whether teachers' knowledge of the basic components of the NOS differs gender. According to some curriculum documents and literature (American Association for the Advancement of Science, 2007; National Research Council, 2012; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003), one of the aspects of the NOS is knowing that both women and men are involved in, and contribute to, science.

NOS educators should adopt an attitude that strongly supports the idea that there are no gender differences when studying science (Chen, et. al. 2013). Gender stereotypes are often built on the belief that men have higher levels of cognitive ability (superior intelligence, the capacity for genius etc.) than women (Emran, et. al., 2020). It is important to understand whether teachers are affected by these prejudices. NOS knowledge should not differ according to the gender of the teacher. Some studies have found a significant difference in teachers' and pre-service teachers' NOS knowledge in terms of gender (e.g. Beşli, 2008; Doğan Bora, 2005; Gül, 2016; Gürgil, 2019; Preece & Baxter, 2000; Saraç & Cappellaro, 2015; Sjödin, 2002; Williams, et. al., 2007), while others have not (e.g. Kirman-Çetinkaya & Laçin-Şimşek, 2012; Şenler & İrven, 2016; Yenice, Özden & Hiğde, 2017).

Teachers provide society with knowledge about the NOS. It is therefore important to first determine the structure and level of pre-service teachers' NOS knowledge. It should also be determined which variables may affect the level of knowledge of the NOS components, and the possible relationship of these variables with pseudo-scientific beliefs. No study has been found in the literature investigating the relationship between the components of the NOS. Teachers should have a scientific point of view in order to provide their students with a scientific perspective. A teacher who aims to give students the ability to distinguish between what is scientific and what is not, should first be able to make this distinction for themselves. It is thus important to examine the relationship between the two domains. This may allow NOS educators to update their own training according to these differences. For this reason, the research questions of this study were as follows:

- What is pre-service teachers' level of NOS knowledge?
- What is pre-service teachers' level of pseudo-scientific beliefs?
- Is there any relationship between the components of NOS knowledge and pseudo-scientific beliefs?
- Is there any significant difference between the level of pre-service teachers' NOS knowledge and pseudo-scientific beliefs in terms of their discipline?
- Is there any significant difference between the level of pre-service teachers' NOS knowledge and pseudo-scientific beliefs in terms of gender?

The hypotheses of this study were determined as follows:

- Hyp1: Pre-service teachers' level of NOS knowledge is sufficient and they have a low level of pseudo-scientific beliefs.
- Hyp2: There is no relationship between the components of NOS knowledge and pseudo-scientific beliefs.
- Hyp3: There is no significant difference between the level of pre-service teachers' NOS knowledge and pseudo-scientific beliefs in terms of the discipline.
- Hyp4: There is no significant difference between the level of pre-service teachers' NOS knowledge and pseudo-scientific beliefs in terms of gender.

To sum up, this study aimed to determine the levels of pre-service teachers' NOS knowledge, pseudo-scientific beliefs, and the relationship between the components of NOS knowledge and pseudo-scientific beliefs. It also aimed to determine whether NOS knowledge and pseudo-scientific beliefs depended on the variables of discipline and gender.

## Theoretical Framework

### What is the NOS?

Like the concepts and theories, it involves, science itself also evolves continuously (Abd-El Khalick & Lederman, 2000). NOS has been defined differently over a long period of time by various philosophical, sociological, and historical thinkers (Abd-El-Khalick & Lederman, 2000). However, Emran, et al. (2020) state that most researchers agree that the NOS relates to scientific knowledge that is empirical, tentative, theory-laden, creative, inferential, socially constructed, and structured in propositions or sets of propositions, such as scientific laws and theories, which are distinct from each other (e.g. Abd-El-Khalick 2012; Erduran & Dagher, 2014; Lederman & Lederman, 2014). Science teachers, scientists, historians, philosophers, and science sociologists have reached a similar consensus on the aspects of the NOS (Osborne, et. al., 2003). This conceptualization has been called the "general aspects" conceptualization or the "consensus view" of the NOS (Kampourakis, 2016).

The NOS includes both the nature of scientific knowledge and the nature of scientific research (Emran, et. al., 2020). On the basis of international curriculum documents and the literature (American Association for the Advancement of Science, 2007; National Research Council, 2012; Osborne, et. al. 2003), the following aspects of scientific information are included in the conceptualization of the NOS (Emran, et. al., 2020): (a) scientific claims are reasoned and empirically-based; (b) most experiments or observations can be repeated by researchers in a variety of settings; (c) scientific knowledge is durable but uncertain. It can be changed significantly in the light of new findings or perspectives; (d) new methods and technological innovations contribute to change; (e) science is made by people who are constrained by their society and culture; (f) both women and men are involved in science and contribute to science.

According to the consensus view, there are seven to 10 NOS components that can be taught in the school context and be used to determine students' misconceptions about the NOS. Even among advocates of the consensus view, however, the terminology employed can change. For instance, they are divided as to whether NOS is domain-general or domain-specific (Kampourakis, 2016). Some researchers claim that the NOS is domain-general, so all sciences share some common features and common epistemological claims can be made for all sciences (Abd-El-Khalick, 2012; Irzik & Nola, 2011; Kampourakis, 2016; Lederman & Lederman, 2014; Niaz, 2010; Osborn et al., 2003). Others claim that NOS is domain-specific, so every scientific discipline has its own unique methodological, ontological, and epistemological features (Schizas, Psillos, & Stamou, 2016).

Some researchers have criticized the consensus view and suggested alternatives. There have also been advocates for the view that NOS should be taught by asking questions that go deeper into the nature of scientific studies, rather than focusing on specific components or principles (Clough, 2011). This approach focuses on what the NOS is as well as how it should be taught. Matthews (2012) proposed using the term "features of science" (FOS) instead of NOS, based on the idea that it was "more philosophically and historically refined and developed to benefit teachers and students". In addition, several researchers have argued for the use of the history of science (HOS) to teach the NOS (McComas, 2010; Rudge, Cassidy, Fulford, & Howe, 2014). The HOS provides an extremely contextual approach to NOS teaching, which can introduce human agency to the topic. However, empirical studies on the use of the HOS to teach the NOS are inconsistent (Williams & Rudge, 2019).

Irzik and Nola (2011) suggested the "Family Resemblance Approach", suggesting that the conceptualization of the general aspects of the NOS neglected the differences between scientific disciplines due to its weakness. This approach is based on the understanding that some members of a family are more similar to each other than others. They demonstrated that although scientific disciplines have some common aspects, this is not sufficient to define science. They proposed four specific categories: (a) research processes, (b) goals and values, (c) methods and methodological rules, and (d) products. These categories were expanded by Dagher and Erduran (2016). However, this approach is more difficult to apply in a school context than the consensus view is (Cofré et al., 2019).

There is still a lot to be done to define the best model for teaching the NOS (Lederman & Lederman 2014). For example, it is not yet known why some aspects or features of the NOS are more difficult to understand than others (Mesci & Schwartz, 2017); whether some aspects of the NOS lead to the implicit learning of other aspects (Seung, Bryan & Butler, 2009), or whether there is a real relationship between students' understanding of the NOS and scientific concepts (Lederman, 2007). In this study, the consensus view of the NOS was taken into consideration. The scale used as a data collection tool in the study, was developed according to the improved form of the general aspects approach (Özcan & Turgut, 2014).

Everyone should have a basic knowledge of science-related concepts and the NOS. However, the NOS is associated more with those who study the natural sciences than those who study the social sciences and arts. The education that these two groups received causes their worldviews to be completely different (Snow & Collini, 2012). This difference also affects their perspective on the NOS. For example, Arı (2010) concluded that pre-service science teachers have more accurate knowledge of scientific theories and laws than pre-service elementary school teachers. Some pre-service social sciences teachers stated that scientific methods could be used to explain supernatural events, on the other hand, some stated that supernatural events were not within the limits of science (Gürgil, 2019).

Gender is another variable where knowledge about the NOS may differ due to social stereotypes. Some studies state that males have more knowledge of the NOS than females (Yenice et al., 2017). Nevertheless, teachers should adopt a position that strongly supports the idea that there are no gender differences while studying or working in scientific disciplines (Chen et al., 2013). Gender stereotypes suggest that males are more intelligent and more scientifically inclined and that females have a lower chance of success in science (Fredricks, Hofkens, Wang, Mortenson, & Scott, 2018). As a result of these ideas, teachers may encourage boys more than girls and have lower expectations of girls (Makarova & Herzog, 2015). When girls believe this stereotype, it may adversely affect their performance. For this reason, it is important that teachers are not affected by these stereotypes.

**Relationship between NOS aspects**

There has not been enough scientific research in the literature regarding the relationship between the aspects of the NOS. There are various findings regarding these aspects. It is known that individuals find it hard to properly grasp concepts related to science, including observation, inference, laws and theories. For example, a significant number of people think that there is a hierarchical relationship between theories and laws (Abd-El-Khalick, 2005). This relationship, from the most unreliable to the most reliable, is as follows: hypotheses, theories, and laws (Abd-El-Khalick, 2005; Akerson, et al., 2006). Theories and laws are different components of scientific knowledge. Theories explain why and how an event happened in that specific way; however, laws describe how it happened at all. The idea that there is a hierarchical relationship between theories and laws is very resistant to change (Küçük, 2008). In this regard, improving some components of NOS knowledge is more difficult than others (Mesci & Schwartz, 2017). In particular, these views regarding theories and laws are harder to change (Akerson, et. al., 2000; Köseoğlu, et al., 2010). For example, in one study, the majority of pre-service preschool teachers accepted that scientific theories were subject to change, but claimed that scientific laws were correct and immutable (Erdaş Kartal & Ada, 2018).

There are other misconceptions about the NOS, especially with regard to scientific concepts. According to Cofré et. al. (2019), the most common misconceptions are: "(1) hypotheses become theories and theories become laws; (2) science is an objective enterprise, and scientists do not use their experience and background to analyze results or propose explanations; (3) scientific knowledge is an immutable truth; and (4) only one scientific method exists." Some aspects of NOS are still debated by scientists. According to Uyar (2016), even philosophers of science agree that there is no universal criterion for determining the limits of science yet. It can thus be understood why people also have difficulties determining the limits of science.

In recent years, some approaches to NOS teaching have emerged through experimental studies (e.g. Abd-El-Khalick & Lederman 2000; Lederman 2007). However, to what extent these misconceptions have an effect on people's understanding of the NOS, and the relationships between them, have not yet been clearly revealed.

**What is Pseudo-Science?**

With the positivist approach that started with Comte in the 19th century, studies on the HOS also began. The main purpose of the study of the HOS was not to produce a narrative of the development of science, but to examine the philosophical and epistemological problems of science and to reveal its nature in this way (Topdemir & Unat, 2019). Two of the most important questions in science are "What is the scope of science?" and "What are the limits of scientific problems?". While doing science, the following should be decided: (i) how to answer questions (what method does science use?), and (ii) how to place limits on the scientific and the non-scientific (what are the limitations of science?).

The responses of the logical positivism of the Vienna Circle to the question of what cannot be scientific led to a discussion of what "seems scientific but not" with the development of Popper's principle of falsifiability in the late 1920s (Uyar, 2016). The problem of discriminating science from pseudo-science is called "Popper's discriminatory problem" (or the "boundary problem in science"). Many criteria, such as objectivity, verifiability, testability (or confirmability), changeability, replicability, cumulativeness, progressiveness, factuality, and predictability have been proposed as the criteria for discrimination in the discussions focusing on the characteristics of science (Bunge, 2011; Cortinas-Rovira, Alonso-Marcos, Pont-Sorribes, & Escriba-Sales, 2015). Some thinkers have focused directly on the characteristics of pseudo-science, such as isolation – which means that it occurs far from mainstream science and is rarely part of in academic activities –, abuse of empirical data, lack of self-correction mechanisms, not being open to new hypotheses and methods, and reliance on beliefs rather than data (Bunge, 2011).

Although most scientists are aware of the nature and limitations of science, it may be more difficult for students who do not fully grasp the NOS to distinguish discourses disguised as scientific discourses from true knowledge. For many students, science has such great authority that their attitude toward ideas claiming to be "scientific" can be quite uncritical (Keranto, 2001). According to the results of a survey conducted at Hollins College, Virginia, 37% of students believed in ghosts, 64% in telepathy, and 46% believed that plants would grow faster if people talked to them (Woods, 1984). Another survey conducted at Concordia College in Montreal, Canada found that 85% of students believed in extrasensory perception (ESP), 55% in astrology, 49% in psychic healing, and 43% in ghosts (Gray, 1984). Such beliefs are still common in the general population even today (Silva & Woody, 2022). The media supports these beliefs and contributes to their dissemination.

Some studies have concluded that pseudo-scientific beliefs are mostly seen in females, especially with regard to paranormal beliefs (Gürgil, 2019; Preece & Baxter, 2000; Sjödin, 2002; Williams, et al., 2007). Preece and Baxter (2000) also state that females are less skeptical about pseudo-scientific beliefs. However, this may relate to the type of pseudo-scientific beliefs. For example, males tend to believe in pseudo-scientific claims like the existence of UFOs, and aliens, although females believe more in pseudo-scientific claims such as fortune-telling and horoscopes.

**NOS and Pseudo-Science**

Pseudo-science can be defined as all claims that lack scientific evidence and credibility, although these are often said to be scientific (Shermer, 2002). In other words, even if practitioners of pseudo-science state that their methods and knowledge they have is scientific, these claims are often not in conformity with scientific standards and do not have the chance to be verified both experimentally and theoretically (Pavić, 2013; Preece & Baxter, 2000). When a claim about the universe arises whose accuracy cannot be tested within a scientific framework, it is clearly a pseudo-scientific claim.

When scientists evaluate whether there is a cause-and-effect relationship between two events, they try to correlate them by creating a sample. For pseudo-scientists, it is enough to show that they have some similarities with each other to establish or imply some relationship between the two events. This characteristic feature of pseudo-scientific knowledge makes it difficult for the general public to distinguish between science and pseudo-science (Tseng, Tsai, Hsieh, Hung, & Huang, 2014).

Believers in pseudo-science do not have a particular personality trait. It is possible that these individuals believers do not have any specifically distinct characteristics, such as a “will to believe”, that are different from those of non-believers (Lindeman, 1998). According to Lindeman (1998), individuals believe in pseudo-scientific ideas because they meet many basic social needs and make it easier to explain and make sense of unexpected events encountered in everyday life. Many pseudo-sciences offer a vision of a world that is more coherent, controllable, and acceptable (Lindeman, 1998).

It is known that the existence of pseudo-scientific beliefs makes it difficult to grasp the NOS (Qtait, Abu Liel, Massad, & Asfour, 2021). Instead, exercises to distinguish between pseudo-science and science improve individuals’ epistemological perspectives and facilitate understanding of the NOS (Ayvacı & Bağ, 2016). Good (2012) claims that studying NOS will not help students understand what pseudo-science is. He emphasizes that students should learn clearly through the examples so that they can recognize pseudo-science when they see it.

## Method

This study used the survey method to determine pre-service teachers' pseudo-scientific beliefs and their NOS knowledge. The essence of the survey method can be explained as “questioning individuals on a topic or topics and then describing their responses” (Jackson, 2011). To test the hypotheses, the data collected from pre-service teachers with the Likert scales were first analyzed by descriptive methods, and then the inferential statistics method was used.

### Study Group

Data were collected from 215 pre-service teachers who were attending a state university in Ankara, Turkey. The sample was selected randomly from among sophomore students in the Faculty of Education. Data were collected in a manner that respected ethical practices and research on human subjects. The aim of the research was clearly stated to the subjects and the research group was chosen from those pre-service teachers who volunteered. In addition, no personal information (even their names) other than the gender and department of the pre-service teachers was requested. Thus, the identities of the subjects participating in the research were kept confidential. The participants were studying different disciplines, namely, physics teaching (N=28), science teaching (N=5), mathematics teaching (N=67), social sciences teaching (N=66), elementary school teaching (N=1), preschool teaching (N=8), foreign languages teaching (N=26), geography teaching (N=1), music teaching (N=3), art teaching (N=2), and psychological counseling and guidance (N=8). They were therefore classified into two groups: Natural Sciences and Mathematics Teaching (NSMT), which contained physics teaching, science teaching, and mathematics teaching; and Social Sciences and Art Teaching (SSAT) which contained the remainder. The demographics of the sample are given in Table 1.

Table1. Demographics of Sample

| Field / Gender | Female | | Male | | Total | |
|---|---|---|---|---|---|---|
| | N | % | N | % | N | % |
| NSMT | 82 | 82.00 | 18 | 18.00 | 100 | 46.51 |
| SSAT | 90 | 78.26 | 25 | 21.74 | 115 | 53.49 |
| Total | 172 | 80.00 | 43 | 20.00 | 215 | 100.00 |

As shown in Table 1, most of the pre-service teachers were female (80%) and the rest were male. 46.51% of the pre-service teachers were studying NSMT and 53.49% were studying SSAT. The data were collected from the sample in February 2020, before pandemic restrictions began.

### Data Collection Tools and Analysis of data

To achieve the purpose of the study, two different Likert scales were applied to the sample. The first scale, which will be called Scale 1 throughout the study, was the Pseudo-Scientific Beliefs Scale (PSBS). This was developed by Çetinkaya and Taşar (2018). The scale has 21 items, and the Cronbach’s alpha coefficient was found to be

.849. This scale was applied to determine the level of the pre-service teachers' pseudo-scientific beliefs.

The second scale was applied to obtain the views of pre-service teachers about the NOS. This scale, which will be called Scale 2 throughout the study, was the Nature of Science Beliefs Scale (NOSBS). Scale 2 was developed by Özcan and Turgut (2014). It consists of 37 items and the Cronbach's alpha coefficient was found to be .632. Although .70 and above is widely accepted as the value of a reliability coefficient in science education studies, many studies also consider lower values acceptable (Taber, 2017). Hair, Black, Babin, Anderson and Tatham (2013) noted that a value of .70 is generally agreed upon as an acceptable value; however, they consider that values as low as .60 may be acceptable for exploratory research. Nehring et al. (2015) stated that a test about chemistry knowledge with an alpha value of .55, and which they used in their study, could be considered reliable because "conceptual knowledge may constitute a noncoherent latent construct across a multitude of students". Berger and Hänze (2015) found the alpha coefficient value of the knowledge test they used in their study on the jigsaw learning method to be .45 for the pre-test and .60 or the post-test. They attributed this situation to the broad range of knowledge measurements tested with a limited number of test items. That is, the internal consistency/item equivalence was not expected to be high since the different physics concepts were tested within one instrument. If a scale is multifactorial, a relatively low alpha value does not mean that the scale is not reliable. The items of both scales are presented in the Appendix.

In addition, both scales had been previously validated by their developers in terms of content and construction. To provide construct validity of scales, the Kaiser-Mayer-Olkin (KMO) and Bartlett Test of Sphericity was performed. The KMO values were found to be .81 (Scale 1) and .74 (Scale 2). Similarly, the Chi-Square values (Scale 1: $x^2$ = 2089.19, Sd = 561, p <.00; Scale 2: $x^2$ = 4091.37, Sd = 666, p <.00) obtained as a result of the Bartlett test, which was used to examine whether the data was normally distributed in multivariate analysis, was found to be significant. All the factors of both scales are given in Table 2.

As shown in Table 2, Scale 1 consists of three factors, and Scale 2 consists of seven factors. The data were assessed with the help of computer software. Both scales are Likert-type scales: The respondents express their level of agreement to items containing true or false information by choosing options 1-5. In the evaluation, items that represent false (unscientific) responses are reverse-coded. That is, among the Likert items, those which gave correct information were scored from 5 to 1, while those which gave false information were scored from 1 to 5. For all items, 1 point represents an agreement with false information and 5 points represents an agreement with true information. While interpreting descriptive statistics, responses were grouped by levels.

The evaluation criteria were determined by considering the structure of the scales (Kızılcık, et. al., 2007). All the scales are five-point Likert scales. Accordingly, the responses are handled in five levels. The level is whatever range corresponds to the mean of responses to the entire scale or each factor of the scale. A respondent can respond 1 to 5 on each item. That is, no respondent can choose less than 1 or more than 5 points. The average must be between 1-5. The range of 1 to 5 is 4. If we want to divide this range into five equal levels, we have to move to the next level every time we add 4/5 = 0.8. Since a respondent can choose at least 1 point, the starting number of the first level has to be 1.00. For example, if the range 1.00-1.79 is the first level, the range 1.80-2.56 should be the second level.

Table 2. Factors of Scales

| Scales | Factors | Number of Items | Items |
|---|---|---|---|
| Scale 1: PSBS | S1-F1: Pseudo-Physical Claims | 9 | 2, 3, 8, 9, 11, 12, 13, 16, 18 |
| | S1-F2: Pseudo-Predictive Claims | 6 | 4, 5, 6, 7, 15, 17 |
| | S1-F3: Pseudo-Medical Claims | 6 | 1, 10, 14, 19, 20, 21 |
| | Total | 21 | |
| Scale 2: NOSBS | S2-F1: Changes in Scientific Knowledge | 6 | 1, 8, 15, 20, 23, 30 |
| | S2-F2: Discrimination Between Observation and Inference | 4 | 2, 13, 21, 25 |
| | S2-F3: Scientific Method(s) | 4 | 3, 19, 29, 32 |
| | S2-F4: Creativity and Imagination | 5 | 4, 9, 17, 24, 37 |
| | S2-F5: Socio-Cultural Impact | 8 | 5, 7, 16, 22, 26, 28, 34, 36 |
| | S2-F6: Scientific Laws and Theories | 4 | 6, 12, 18, 33 |
| | S2-F7: The Postulates and Limits of Science | 6 | 10, 11, 14, 27, 31, 35 |
| | Total | 37 | |

The range of each level is called the evaluation range. The ranges determined for the levels are obtained by adding the evaluation range to the Likert points. The ranges that correspond to each level are called level ranges. The evaluation range was calculated according to the following formula, and the assessment criteria according to the evaluation range are presented in Table 3 and pictured in Figure 1.

Evaluation Range = (Score Range) / (Number of Categories) = (5-1) / 5 = 4 / 5 = 0.8

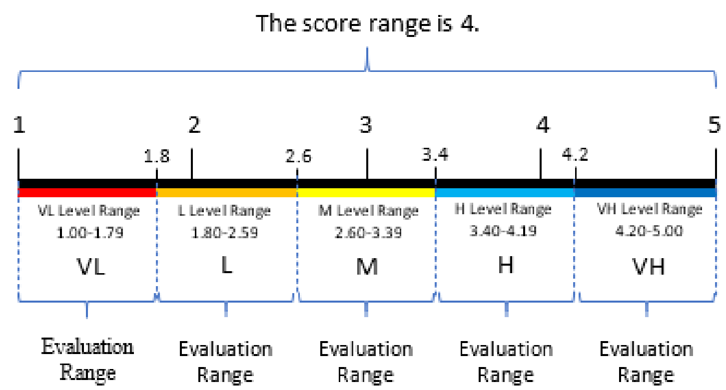



Figure 1. Visualization of Assessment Criteria

As seen in Table 3, 2.59 and below are considered low and very low, while 3.40 and above are considered as high and very high levels. Between 2.60 and 3.39 is considered a moderate level.

Table 3. Assessment Criteria

| Level Range | Level |
|---|---|
| 1.00 - 1.79 | Very Low (VL) |
| 1.80 - 2.59 | Low (L) |
| 2.60 - 3.39 | Moderate (M) |
| 3.40 - 4.19 | High (H) |
| 4.20 - 5.00 | Very High (VH) |

In addition to descriptive statistics, some hypotheses were tested using inferential statistics. The Pearson correlation coefficient was used to determine whether there was a significant relationship between the responses to the factors of the scales. In addition, differences between the sample groups and whether the differences were significant were examined with the help of two-way MANOVA.

## Results

First, descriptive analysis was performed to determine the levels of pre-service teachers' NOS knowledge and pseudo-scientific beliefs and to thus test Hyp1. Descriptive statistics such as sample size (N), mean, standard deviation, variance, median, kurtosis, and skewness of the data obtained from scales and their factors were determined. Responses were also categorized based on mean according to assessment criteria (see Table 4).

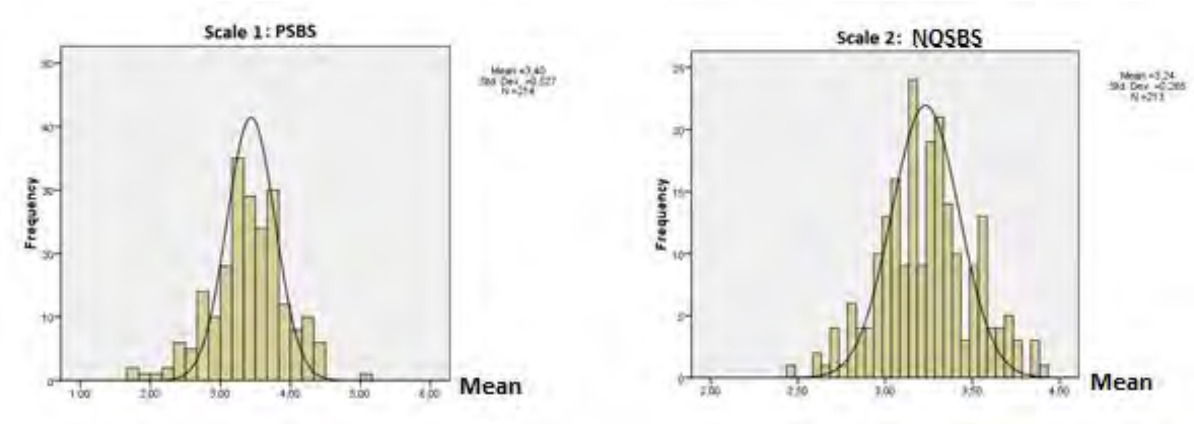
Table 4. Descriptive Statistics of Scales

| Scale | Factor | N. of Items | N | Mean | Level | Median | Std. Dev | Var. | Skewness | | Kurtosis | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Stat. | Std. Er. | Stat. | Std. Er. |
| Scale 1: PSBS | S1-F1 | 9 | 214 | 3.627 | H | 3.67 | .568 | .323 | -.482 | .166 | .617 | .331 |
| | S1-F2 | 6 | 214 | 3.237 | M | 3.33 | .635 | .403 | -.172 | .166 | .228 | .331 |
| | S1-F3 | 6 | 214 | 3.230 | M | 3.33 | .593 | .352 | -.333 | .166 | .681 | .331 |
| | Total | 21 | 214 | 3.402 | H | 3.43 | .527 | .277 | -.309 | .166 | .642 | .331 |
| Scale 2: NOSBS | S2-F1 | 6 | 213 | 3.725 | H | 3.83 | .532 | .283 | -.118 | .167 | .301 | .332 |
| | S2-F2 | 4 | 213 | 3.268 | M | 3.25 | .491 | .241 | .439 | .167 | .764 | .332 |
| | S2-F3 | 4 | 213 | 2.955 | M | 3.00 | .486 | .237 | -.249 | .167 | 1.149 | .332 |
| | S2-F4 | 5 | 213 | 3.193 | M | 3.20 | .638 | .407 | -.242 | .167 | -.067 | .332 |
| | S2-F5 | 8 | 213 | 3.484 | H | 3.50 | .403 | .163 | .092 | .167 | 1.025 | .332 |
| | S2-F6 | 4 | 213 | 2.754 | M | 2.75 | .771 | .595 | -.288 | .167 | -.343 | .332 |
| | S2-F7 | 6 | 213 | 2.944 | M | 2.83 | .356 | .126 | .237 | .167 | .208 | .332 |
| | Total | 37 | 213 | 3.237 | M | 3.24 | .265 | .070 | .032 | .167 | -.025 | .332 |

As seen in Table 4, Scale 1 had a higher mean than Scale 2 in total. Scale 1 was at a high level and Scale 2 was at a moderate level overall. In terms of factors, it can be seen that S2-F6 (Scientific Laws and Theories) had the lowest, and S2-F1 (Changes in Scientific Knowledge) had the highest mean. In total, seven of 10 factors were at the moderate level and 3 (S1-F1, S2-F1, S2-F5) were at the high level. The only high-level factors were Changes in Scientific Knowledge, Pseudo-physical Claims, and Socio-cultural Impact, with their respective scores in that order.

The responses to Scale 1 showed that the pre-service teachers had a high-level awareness of Pseudo-physical Claims, but they had a moderate-level awareness of Pseudo-predictive Claims and Pseudo-medical Claims. The responses to Scale 2 showed that pre-service teachers had high-level awareness of the Changes in Scientific Knowledge and Socio-cultural Impact components of the NOS, but they had moderate-level awareness of the other components. Their knowledge may thus not have been sufficient, as most of the factors were at a moderate level. It was expected that pre-service teachers would be at a higher level than common people who will go on to undertake the task of educating individuals using a scientific approach. Therefore, Hyp1 is rejected.

The kurtosis and skewness values of the scales and their factors can give us information about whether the data have a normal distribution. According to George and Mallery (2010), “A kurtosis value between ±1.0 is considered excellent for most psychometric purposes, but a value between ±2.0 is in many cases also acceptable, depending on the particular application.” Also, Hair, et. al. (2013) say: "Skewness Measure of the symmetry of distribution; in most instances, the comparison is made to a normal distribution … Skewness values falling outside the range of -1 to +1 indicate a substantially skewed distribution." Accordingly, the data show a normal distribution. The mean and median values are close to each other and they support normal distribution. Figure 2 shows the distribution curves of Scale 1 and Scale 2.




(a) (b)

Figure 2. Distribution Curves of Scale 1 (a) and Scale 2 (b)

Inferential analysis to test the hypotheses was performed by parametric statistical methods due to the normal distribution of the data. First, whether there is a relationship between scales and their factors was examined with the help of the Pearson Correlation Coefficient to test Hyp2. Table 5 shows the correlation findings between the factors. In Table 5, r is the correlation coefficient and P is the significance value. Values found significant in Table 5 are written in bold (P<0.5). According to Table 5, there were strong, significant, and positive relationships between all the factors of Scale 1. Its factors include the types of pseudo-scientific beliefs. All factors of Scale 1 were positively correlated with each other.

Table 5. Correlations between All Factors of Scales (p<0.5)

| Scales | Factors | | Scale 1: PSBS | | | | Scale 2: NSBS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | S1-F1 | S1-F2 | S1-F3 | Total | S2-F1 | S2-F2 | S2-F3 | S2-F4 | S2-F5 | S2-F6 | S2-F7 | Total |
| Scale 1: PSBS | S1-F1 | r | 1 | | | | | | | | | | | |
| | | P | * | | | | | | | | | | | |
| | S1-F2 | r | **.731** | 1 | | | | | | | | | | |
| | | P | **.000** | * | | | | | | | | | | |
| | S1-F3 | r | **.695** | **.565** | 1 | | | | | | | | | |
| | | P | **.000** | **.000** | * | | | | | | | | | |
| | Total | r | **.937** | **.864** | **.837** | 1 | | | | | | | | |
| | | P | **.000** | **.000** | **.000** | * | | | | | | | | |
| Scale 2: NOSBS | S2-F1 | r | **.154** | -.015 | .101 | .097 | 1 | | | | | | | |
| | | P | **.025** | .830 | .142 | .157 | * | | | | | | | |
| | S2-F2 | r | .023 | -.043 | -.008 | -.007 | **.236** | 1 | | | | | | |
| | | P | .743 | .536 | .911 | .919 | **.001** | * | | | | | | |
| | S2-F3 | r | .084 | -.045 | -.001 | .023 | **.225** | .101 | 1 | | | | | |
| | | P | .224 | .510 | .987 | .743 | **.001** | .141 | * | | | | | |
| | S2-F4 | r | -.052 | -.108 | **-.140** | -.107 | **.168** | .059 | **.210** | 1 | | | | |
| | | P | .449 | .116 | **.041** | .119 | **.014** | .391 | **.002** | * | | | | |
| | S2-F5 | r | **.202** | .033 | .100 | **.136** | **.349** | **.228** | .120 | .128 | 1 | | | |
| | | P | **.003** | .632 | .144 | **.047** | **.000** | **.001** | .081 | .062 | * | | | |
| | S2-F6 | r | **-.174** | **-.152** | **-.161** | **-.186** | .006 | -.060 | .111 | **.486** | -.083 | 1 | | |
| | | P | **.011** | **.026** | **.019** | **.007** | .928 | .386 | .106 | **.000** | .230 | * | | |
| | S2-F7 | r | -.059 | .008 | -.074 | -.050 | .060 | .030 | -.031 | **.245** | .058 | **.165** | 1 | |
| | | P | .389 | .902 | .284 | .471 | .387 | .658 | .652 | **.000** | .403 | **.016** | * | |
| | Total | r | .054 | -.090 | -.046 | -.023 | **.600** | **.380** | **.425** | **.682** | **.543** | **.496** | **.393** | 1 |
| | | P | .437 | .189 | .500 | .742 | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | **.000** | * |

S1-F3 (Pseudo-medical Claims) and S2-F4 (Creativity and Imagination) were related negatively and significantly. Those who had more pseudo-medical beliefs thought that there was less creativity and imagination in science. S1-F1 (Pseudo-physical Claims) was related positively and significantly to S2-F1 (Changes in Scientific Knowledge) and S2-F5 (Socio-cultural Impact). When respondents had fewer pseudo-physical beliefs, their ability to comprehend the changeability of scientific knowledge and the relationship of science with socio-cultural effects was higher. So, Hyp2 was rejected.

S2-F1 (Changes in Scientific Knowledge) was positively and significantly related to S2-F2 (Discrimination between Observation and Inference), S2-F3 (Scientific Method(s)), S2-F4 (Creativity and Imagination), S2-F5 (Socio-cultural Impact). Pre-service teachers who were aware of the changeability of scientific knowledge were also more aware of the scientific methods, the role of socio-cultural influences, creativity, and imagination in science.

S2-F2 (Discrimination between Observation and Inference) and S2-F5 (Socio-cultural Impact) were significantly and positively related. It can be said that being aware of the role of sociocultural effects in science is about being aware of the distinction between observation and inference.

S2-F4 (Creativity and Imagination) was significantly and positively related to S2-F6 (Scientific Laws and Theories) and S2-F7 (The Postulates and Limits of Science). A significant and positive relationship was also found between S2-F3 (Scientific Method(s)) and S2-F4 (Creativity and Imagination), and between S2-F6 (Scientific Laws and Theories) and S2-F7 (The Postulates and Limits of Science).

The next phase of the study examined whether there was a statistically significant difference between demographic groups. The mean scores of the groups were first determined and can be seen in Table 6.

Table 6. Group Means

| Scale | Factors | NST | | SSAT | | Total | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | Female | Male | Female | Male | Female | Male | NST | SSAT |
| Scale 1: PSBS | S1-F1 | 3.65 | 3.42 | 3.60 | 3.77 | 3.63 | 3.60 | 3.65 | 3.60 |
| | S1-F2 | 3.23 | 3.10 | 3.24 | 3.34 | 3.24 | 3.22 | 3.23 | 3.24 |
| | S1-F3 | 3.18 | 3.27 | 3.24 | 3.35 | 3.21 | 3.31 | 3.18 | 3.23 |
| | Total | 3.40 | 3.29 | 3.40 | 3.53 | 3.40 | 3.41 | 3.40 | 3.39 |
| Scale 2: NOSBS | S2-F1 | 3.82 | 3.73 | 3.65 | 3.66 | 3.74 | 3.70 | 3.82 | 3.65 |
| | S2-F2 | 3.38 | 3.26 | 3.19 | 3.17 | 3.29 | 3.22 | 3.38 | 3.19 |
| | S2-F3 | 2.93 | 2.84 | 2.98 | 3.04 | 2.95 | 2.94 | 2.93 | 2.98 |
| | S2-F4 | 3.43 | 3.05 | 3.02 | 3.14 | 3.22 | 3.10 | 3.43 | 3.02 |
| | S2-F5 | 3.56 | 3.29 | 3.45 | 3.47 | 3.51 | 3.38 | 3.56 | 3.45 |
| | S2-F6 | 2.90 | 2.87 | 2.56 | 2.89 | 2.73 | 2.88 | 2.90 | 2.56 |
| | S2-F7 | 3.01 | 3.01 | 2.85 | 3.00 | 2.93 | 3.01 | 3.01 | 2.85 |
| | Total | 3.40 | 3.29 | 3.40 | 3.53 | 3.24 | 3.21 | 3.34 | 3.15 |

As can be seen in Table 6, there are mostly no clear differences between the means of the groups. However, whether the existing differences are significant or not had to be examined to test Hyp3 and Hyp4. A two-way multivariate ANOVA (MANOVA) was conducted with gender and discipline as independent variables, and with scores for the scales and scores for the factors as dependent variables. MANOVA, unlike ANOVA, does not increase Type I error. Before the two-way MANOVA is conducted, Box's Test of Equality of Covariance Matrices and Levene's Test of Equality of Error Variances are examined. This is because, to use MANOVA, the following assumption must be met: "The population covariance matrices of each group are equal (this is an extension of homogeneity of variances required for univariate ANOVA)" (Tabachnick & Fidell, 2013). According to the result of Box's Test of Equality of Covariance Matrices, the null hypothesis was that the observed covariance matrices of the dependent variables were equal across groups (Box's M=68.615; F=1.190; P>.05). The findings for Levene's Test of Equality of Error Variances can be seen in Table 7.

Table 7. Levene's Test of Equality of Error Variances for all scales (p<.05).

| Scales | Factors | F | df-1 | df-2 | Sig. (p) |
|---|---|---|---|---|---|
| Scale 1: PSBS | S1-F1 | 2.191 | 1 | 211 | .140 |
| | S1-F2 | .476 | 1 | 211 | .491 |
| | S1-F3 | 3.021 | 1 | 211 | .084 |
| | Total | .014 | 1 | 211 | .907 |
| Scale 2: NOSBS | S2-F1 | 4.742 | 1 | 211 | .031 |
| | S2-F2 | 2.789 | 1 | 211 | .096 |
| | S2-F3 | 2.105 | 1 | 211 | .148 |
| | S2-F4 | .351 | 1 | 211 | .554 |
| | S2-F5 | .070 | 1 | 211 | .792 |
| | S2-F6 | .092 | 1 | 211 | .762 |
| | S2-F7 | 2.191 | 1 | 211 | .140 |
| | Total | .476 | 1 | 211 | .491 |

As shown in Table 7, there was no significant value for all factors of all scales, except S2-F1. This result showed that the data were mostly suitable for two-way MANOVA. Gender was considered covariance. The results of the two-way MANOVA can be seen in Table 8.

Table 8. MANOVA Results by Gender, Field, and Field*Gender (p<.05)

| Effect | Pillai's Trace | F | Hypothesis df | Error df | Sig. (p) | Partial Eta Squared ($\eta^2$) |
|---|---|---|---|---|---|---|
| Field | .111 | 1.301 | 10.000 | 200.000 | .008 | .111 |
| Gender | .057 | .842 | 10.000 | 200.000 | .292 | .057 |
| Field * Gender | .074 | 1.169 | 10.000 | 200.000 | .107 | .074 |

There was a significant multivariate effect for the discipline, while there were no significant effects for gender and discipline*gender as shown in Table 8. The results of the analysis show that there was no significant difference between genders in terms of any factor of the scale. In the descriptive statistics for gender, females had a higher mean in Pseudo-physical Claims and Pseudo-predictive Claims and males had a higher mean in Pseudo-medical Claims. But those differences were not significant. The means of the females were higher than males in all the NOS components except Scientific Laws and Theories and The Postulates and Limits of Science in this study. But these differences were also not significant. Hyp4 was confirmed.

For each multivariate procedure, the initial test statistic (given under “Pillai's Trace”) was transformed into a test statistic (given under "F"), which can be compared with an F-distribution with "Hypothesis df" and "Error df" to derive the p-value of the test (given under "Sig. (P)") in Table 8 (Landau & Everitt, 2004). Pillai's Trace was chosen because it is not much affected by small biases in assumptions. This is because there was a small deviation for S2-F1 in Levene's Test of Equality of Error Variances. Partial eta squared shows what percentage of the difference was due to the groups. According to Richardson (2011), the partial eta squared value can be benchmarked against Cohen's criteria of small, medium, and large effects. He defined effect sizes as small when they are <.2. The effect size was small. Regarding pseudo-scientific beliefs and NOS knowledge, there was no significant difference between male or female pre-service teachers. When there is a significant difference in MANOVA results, this indicates that the independent variable has a significant difference from at least one of the dependent variables. But it does not indicate for which dependent variable there is a significant difference. The test performed to determine which dependent variable(s) has/have a significant difference(s) is called the post hoc test (Field, 2013). The post-hoc test was performed.

Table 9. Post-hoc Test Results by Field (p<.05)

| Dep. Var. | Field | Mean | Std. Error | 95% Confidence Interval | | Type III Sum of Squares | df | Mean Square | F | Sig. (p) | Partial Eta Squared ($\eta^2$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L. Bound | U. Bound | | | | | | |
| S1-F1 | NTS | 3.607 | 0.057 | 3.494 | 3.72 | 1.021 | 1 | 1.021 | 3.159 | 0.077 | 0.015 |
| | SSAT | 3.635 | 0.053 | 3.53 | 3.74 | | | | | | |
| S1-F2 | NTS | 3.207 | 0.064 | 3.08 | 3.333 | 0.263 | 1 | 0.263 | 0.645 | 0.423 | 0.003 |
| | SSAT | 3.261 | 0.06 | 3.143 | 3.379 | | | | | | |
| S1-F3 | NTS | 3.198 | 0.06 | 3.079 | 3.316 | 0.009 | 1 | 0.009 | 0.026 | 0.871 | 0.000 |
| | SSAT | 3.257 | 0.056 | 3.147 | 3.368 | | | | | | |
| S2-F1 | NTS | 3.805 | 0.053 | 3.7 | 3.91 | 0.369 | 1 | 0.369 | 1.318 | 0.252 | 0.006 |
| | SSAT | 3.654 | 0.05 | 3.557 | 3.752 | | | | | | |
| S2-F2 | NTS | 3.360 | 0.049 | 3.263 | 3.456 | 0.462 | 1 | 0.462 | 1.966 | 0.162 | 0.009 |
| | SSAT | 3.186 | 0.045 | 3.096 | 3.276 | | | | | | |
| S2-F3 | NTS | 2.911 | 0.049 | 2.814 | 3.008 | 0.05 | 1 | 0.05 | 0.209 | 0.648 | 0.001 |
| | SSAT | 2.990 | 0.046 | 2.9 | 3.08 | | | | | | |
| S2-F4 | NTS | 3.354 | 0.062 | 3.233 | 3.476 | 4.446 | 1 | 4.446 | 11.832 | 0.001 | 0.054 |
| | SSAT | 3.041 | 0.057 | 2.928 | 3.154 | | | | | | |
| S2-F5 | NTS | 3.509 | 0.04 | 3.43 | 3.588 | 0.822 | 1 | 0.822 | 5.169 | 0.024 | 0.024 |
| | SSAT | 3.457 | 0.037 | 3.383 | 3.53 | | | | | | |
| S2-F6 | NTS | 2.893 | 0.076 | 2.742 | 3.044 | 2.568 | 1 | 2.568 | 4.463 | 0.036 | 0.021 |
| | SSAT | 2.624 | 0.071 | 2.484 | 2.765 | | | | | | |
| S2-F7 | NTS | 3.011 | 0.035 | 2.942 | 3.081 | 0.484 | 1 | 0.484 | 3.963 | 0.048 | 0.019 |
| | SSAT | 2.881 | 0.033 | 2.817 | 2.946 | | | | | | |

Values between the mean and the 95% confidence interval on the left side of the Table 9 are the statistics for normal distribution. Type III Sum of Squares explains how much total variation, and df indicates degrees of freedom. As shown in Table 9, significant differences were found for S2-F4 (Creativity and Imagination), S2-F5 (Socio-cultural Impact), S2-F6 (Scientific Laws and Theories), and S2-F7 (The Postulates and Limits of Science) (P<.05). For all factors with significant differences, the differences were in favor of NSMT. Hyp3 was rejected.

## Discussion

### Levels of Pseudo-Scientific Beliefs and NOS Knowledge

The descriptive analysis results showed that the pre-service teachers' pseudo-scientific beliefs were generally at the moderate level but they had a higher mean score in Pseudo-physical Claims than other pseudo-scientific claims. Believing a pseudo-medical claim is riskier than believing a pseudo-physical claim because of the risk of damaging one's health. With regard to pseudo-medical claims, such as those made for weight-loss pills, most pre-service teachers should use scientific criteria in their decisions (Saka & Sürmeli, 2017). This idea supports the relationship between using scientific criteria and making the right decision (Greaves- Fernandez, 2010). Individual should want to learn more before believing a claim that will directly affect their health. However, the result of this present study shows the opposite. The pseudo-scientific claims most believed by the pre-service teachers were pseudo-medical ones. Perhaps this should not be surprising, as medicine was the field about which they had the least knowledge. They may also have been influenced by the use of folk remedies, as these are quite common in their socio-cultural environment. Many of the pre-service teachers in the study came from rural areas in which folk remedies are still used today. They are often more easily available and cheaper than going to a health institution. In addition, if they seem to have worked in the past, even to a small extent, then this strengthens people's faith in them. However, most of the time they do not actually work, but only seem to. Moreover, medicine is a highly complicated and specialized field, with complex, hard-to-learn medical knowledge. Even acquiring literacy in the health sciences requires learning a lot of information. Folk remedies, which are often handed down through word-of-mouth and used on a trial-and-error basis, are comparatively simple. It is thus not surprising that the participants in this study would be willing to use them.

Pseudo-predictive beliefs often relate to supernatural entities, such as ghosts and spirits, as well as alien visitations. These topics are very common in the media and are the subject of many science fiction movies. The pre-service teachers may have been influenced by the media and thus have had lower awareness than expected. On the other hand, pseudo-physical claims are related to more widely known laws of physics. These types of claims have a relationship with familiar topics such as astrology or mind-reading. For example, although many believe in astrology, the idea that astrology is not scientific is often emphasized by scientific circles. The war waged by science educators and narrators against prominent pseudo-scientific fields such as astrology may have had an effect on the results.

Studies on the distinction between science and pseudo-science show that people sometimes have difficulties discriminating between science and pseudo-science (e.g. Afonso & Gilbert, 2010; Çetinkaya, Turgut, Duru & Ercan, 2015; Turgut, 2009). Teachers are no exception. Teachers and pre-service teachers in different fields, including physics, chemistry, biology, languages, the social sciences and mathematics, as well as at different levels, such as preschool or elementary school teaching, often remain undecided about pseudo-science and pseudo-scientific beliefs, and may have difficulties distinguishing between what is scientific and pseudo-scientific (Ağlarcı & Kabapınar, 2016; Gül, 2016; Gürgil, 2019; Kirman-Çetinkaya & Laçin-Şimşek, 2012; Şenler & İrven, 2016; Turgut, 2009; Uçar & Şahin, 2018). Pre-service teachers should have sufficient knowledge about how to discriminate between science and pseudo-science before they enter the profession (Turgut, 2007).

Gürgil (2019) determined that pre-service social sciences teachers had insufficient and contradictory thoughts regarding science and pseudo-science. Pre-service teachers can also be affected by non-scientific knowledge in their daily lives (Saka & Sürmeli, 2017). Most pre-service teachers consider astrology to be a science (Şenler & İrven, 2016). In parallel, the majority of high school students have pseudo-scientific ideas, such as a belief in mind-reading, telepathy and the notion that the lunar cycle can affect people's behavior (Lundström & Jakobsson, 2009). However, as the level of education increases, belief in the presence of paranormal events does decrease (Silva & Woody, 2022). Nevertheless, pre-service teachers may still have pseudo-scientific ideas such as beliefs in luck, horoscopes, and dream interpretation, even when their knowledge of scientific method and knowledge about how to discriminate between science and pseudo-science is quite high (Şenler & İrven, 2016). On the other hand, studies have stated that individuals who grasp the NOS can more easily distinguish what is scientific and what is not (Kirman-Çetinkaya, Laçin-Şimşek, & Çalışkan, 2013).

In this study, the pre-service teachers had a relatively high level of knowledge about the Changes in Scientific Knowledge and Socio-Cultural Impact components of the NOS. According to some studies, the most commonly adopted component of the NOS is the changeability of scientific knowledge (Aslan, 2009; Beşli, 2008; Doğan-Bora, 2005; Morrison, Raab & Ingram, 2009; Özcan, 2011; Saraç & Cappellaro, 2015; Türk, et al., 2018). The vast majority of science teachers think that scientific knowledge may change in the future (Aslan, et al., 2009). Scientific knowledge is reliable and long-lasting. However, this does not mean that it is completely correct or precise. It can change over time, either through evolution or in a revolutionary way (Güneş, 2003). On the other hand, some studies have determined that pre-service teachers do not know enough about the changeability of scientific knowledge (Demir & Akarsu, 2013). Among the NOS knowledge levels, S2-F6 (Scientific Laws and Theories) had the lowest mean, and S2-F1 (Changes in Scientific Knowledge) had the highest mean. The relationship between the two may be related to the misuse of the word "theory" in everyday life. In daily life, "theory" is generally used to mean "assumption". In this sense, it is closer to the concept of "hypothesis". However, this meaning is far from how the word is used when discussing scientific theory. Since hypotheses can be easily dispensed with after testing, they support the concept of the changeability of scientific knowledge. In addition, the idea that socio-cultural influences and scientists' subjectivity affect scientific knowledge also supports the idea that scientific knowledge can change, because subjective knowledge changes more easily than objective. If belief in these two factors ("Changes in Scientific Knowledge" and "Socio-Cultural Impact") is high, it may indicate that there is a relationship between these two components.

Most teachers think that there is a hierarchical relationship between theories and laws (Abd-El-Khalick, 2005; Akerson, et al., 2006; Hanuscin, et al., 2006; Leblebicioğlu, Metin, & Yardımcı, 2012; Saraç & Cappellaro, 2015). This hierarchical relationship, from the most unreliable to the most reliable, is structured as follows: hypothesis, theories, and laws (Abd-El-Khalick, 2005; Akerson, et al., 2006; Hanuscin, et al., 2006; Leblebicioğlu, et al., 2012; Saraç & Cappellaro, 2015; Yalvaç & Craword, 2002). This idea is considered a misconception in the literature (Erdaş Kartal & Ada, 2018). Theories and laws are different components of scientific knowledge. Theories explain why and how an event happened in that specific way; however, laws describe how it actually happened. The idea that there is a hierarchical relationship between theories and laws is quite resistant to change (Küçük, 2008). Improvement in some components of the NOS is more difficult than others (Mesci & Schwartz, 2017). Compared to other components, views regarding theories and laws are more difficult to change (Akerson, et. al., 2000; Köseoğlu, et. al., 2010). For example, in one study, the majority of pre-service preschool teachers accepted that scientific theories were changeable, but claimed that scientific laws were correct and immutable (Erdaş Kartal & Ada, 2018). As discussed above, in daily life the word "theory" is mostly used when talking about speculative claims or a different point of view. “Theory” in this sense may thus be associated with imprecise claims. Everyday language can cause doubts about the reliability of scientific knowledge and lead to misconceptions. Such misconceptions are called “language-based misconceptions” (Kızılcık, 2021).

The factors S2-F6 (Scientific Laws and Theories), S2-F7 (The Postulates and Limits of Science), S2-F3 (Scientific Method (s)), and S2-F2 (Discrimination Between Observation and Inference) were at a moderate level. All of these factors are related to how science is done and the concepts of science. The pre-service teachers’ knowledge in these areas was insufficient. Even in high school textbooks, the scientific method is usually depicted as a series of steps (Irez, 2008). As a result, high-school students tend to think of this method in these terms, as steps which remain unchanged (Leblebicioğlu, Çapkınoğlu, Metin Peten, Schwartz, 2020). The pre-service teachers’ ideas about how science is conducted may be due to misconceptions stemming from the textbooks they used in high school, as most of the sample in this study were in the first years of their university education. To believe that doing science is to do nothing but follow unchanging algorithms, and that these algorithms can be adapted to any subject can lead to misconceptions about the limits and methods of science. It may be that the pre-service teachers did not understand the concepts of science, and that this prevented them from correctly understanding the scientific method. On the other hand, according to Uyar (2016), even philosophers of science agree that there is as yet no universal criterion for determining the limits of science. Therefore, it can be understood why pre-service teachers would also have difficulties determining these limits.

**Relationship between Factors**

Different types of pseudo-scientific beliefs may reinforce each other. A person who has one type of pseudo-scientific belief may be more likely to have other types of such beliefs. According to Lindeman (1998), individuals believe in various pseudo-scientific notions as they meet many basic social needs and make it easier to explain and make sense of unexpected events encountered in everyday life. Pseudo-scientific beliefs are not inherently different from other beliefs, but many pseudo-sciences offer a vision of the world that is more coherent, controllable, and acceptable (Lindeman, 1998). Pseudo-physical Claims positively correlated with Changes in Scientific Knowledge and Socio-cultural Impact. The pre-service teachers who believe that scientific knowledge is changeable and subjective tend to reject pseudo-physical claims. Understanding the NOS makes it easy to properly distinguish between the pseudo-scientific and the scientific (McComas, Clough & Almazroa, 2000).

A negative correlation was found between Creativity and Imagination and Pseudo-medical Claims. Pseudo-science believers consider their beliefs to be scientific (Shermer, 2002). However, their pseudo-scientific “knowledge” often conflicts with proper scientific theories. They may thus place a lot of weight on the idea of Creativity and Imagination, as it supports their point of view. They also tend to believe that they themselves are able to think creatively and flexibly, and that they have a strong imagination. This may lead to them misinterpreting the role of creativity and imagination in science and becoming susceptible to pseudo-medical claims. Beliefs in, for example, alternative medicine are indicative of this. Those who believe that alternative medicine is a natural, creative and successful form of treatment are inclined to pseudo-medical beliefs about its effects.

Pre-service teachers who understand the role of scientific theories and laws have more pseudo-scientific beliefs. These teachers can also be affected by non-scientific knowledge in daily life (Saka & Sürmeli, 2017). On the contrary, some research has been found that as the level of education increases, belief in paranormal events decreases (Silva & Woody, 2022). However, according to Lindeman (1998), "the last decades' explosive increase of scientific information has not decreased popular belief in the pseudo-sciences". It may be the case that the continual increase in scientific knowledge makes science ever more difficult to learn and understand. The pre-service teachers may be choosing to turn to pseudo-scientific beliefs that offer simpler solutions instead of increasingly complex scientific knowledge because pseudo-science offers a more coherent, controllable, and positive view of the world.

This study has determined that the components of the NOS are correlated with, and reinforce each other. Having a sense of the role of creativity and imagination in science may provide an awareness of scientific method and the limits of science. Knowledge of the limits and postulates of science and knowing the role of creativity and imagination and in science may provide the capacity to discriminate between scientific laws and theories.

**Differences between Fields and Gender**

Snow and Collini (2012) stated that NSMT and SSAT cultures perceive science differently. In a study comparing pre-service social fields teachers and pre-service natural sciences, teachers were found to perceive science differently (Ürey, Karaçöp, Göksu & Çolak, 2017). Most pre-service SSAT teachers do not take any specific courses on the NOS during their education (Türk, et al., 2018). NOS is often associated with natural sciences due to positivism. And natural sciences are more associated with positivism than social sciences. Because natural sciences are more based on controlled experiments than social sciences. Therefore, they take more lessons from which they can learn NOS knowledge. In some NSMT departments, courses on the NOS or the Philosophy of Science may be taught as separate courses. On the other hand, in some SSAT departments, such courses are not be available. In the country where this study was conducted, the education system divides students in high school into two main groups after the 9th grade, a natural sciences group and a social sciences group. Specialized education at an early age can make it difficult for students to acquire the knowledge and skills that they should have in other fields.

The needs and priorities of females and males are different (Beşli, 2008; Doğan-Bora, 2005; Saraç & Cappellaro, 2015). Therefore, differences can be expected in the pseudo-scientific beliefs and beliefs about the NOS between males and females. Studies show that females have more paranormal beliefs, such as beliefs in precognition, spiritualism, witchcraft, psychics, and alternative medicine (Aarnio & Lindeman, 2005; Mencken, Bader, Stark, 2008; Mencken, Bader, Kim, 2009; Wilson, 2018). On the other hand, men are more prone to beliefs about aliens (Wilson, 2018). The results of this study do not show that. The types of pseudo-scientific beliefs were determined to be independent of the gender variable. Peltzer (2003) found similar results. The same is true for the components of the NOS. Although problems related to gender equality have decreased, they have not been fully eliminated. However, the decrease in gender stereotypes promoted or reinforced in education may explain the lack of a significant difference.

## Conclusion

Understanding the NOS depends primarily on the correct learning of science-related concepts, such as laws, theories, observation, inference, etc. Failure to acquire these concepts as they are used in science causes the different meanings placed on them in daily life to prevail. If people's understanding of the basic concepts of science is improperly structured, then their entire sense of what science is will be wrong. It is especially important that pre-service teachers have the correct understanding, because they are responsible for passing on this knowledge to future generations.

The changeability of scientific knowledge is often misinterpreted. Not understanding the nature of scientific theories and not understanding that scientific knowledge is changeable are mutually reinforcing. This leads people to question theories based on scientific knowledge. Perceptions about the subjectivity of scientific knowledge also support these misinterpretations. This may then reduce individuals' reliance on scientific knowledge, causing them to turn to pseudoscientific information as alternative information. The main problem is that people may think, "Theories are only assumptions. They are not proven and they can change. Also, the findings of scientists are subjective. So, claims that are today called pseudo-scientific claims may one day become scientific knowledge." This is to misinterpret and misunderstand how specific concepts are used in science. It is a very dangerous way of reasoning, leading to false and inappropriate conclusions.

Having any kind of pseudo-scientific beliefs makes it more likely to have other pseudo-scientific beliefs. One of the reasons for the spread of pseudo-scientific beliefs is that society finds science increasingly complex and difficult to understand. It is critical that science educators simplify scientific information and present it to the public in an appropriate. Social awareness of the unscientific nature of some topics, such as astrology, has increased through the work of science educator. However, this awareness remains insufficient, and many pseudo-scientific beliefs, particularly pseudo-medical beliefs continue to persist. For example, folk remedies are still commonly used.

The pre-service teachers in NSMT areas were slightly more fortunate than the SSAT colleagues. The education they have received provided them with a better understanding of the concepts related to the NOS, although it did not protect them from believing in some pseudo-scientific claims. However, understanding these concepts alone is insufficient to understand the NOS and to be able to distinguish what is scientific from what is not. Although the NSMT pre-service teachers had a more accurate knowledge of the concepts, they had trouble interpreting them. On the other hand, contrary to many scientific studies, the fact that in the current study the gender variable did not affect beliefs about the NOS and pseudo-scientific beliefs may indicate that this knowledge and the ability to discriminate can be provided to both genders in the same way.

## Limitations and Recommendations

The main limitation of this study was that COVID-19 restrictions prevented additional data-collecting methods, such as interviews, from being used. A number of practical problems limited the sample size. Many pre-service teachers could not be reached. Therefore, the number of pre-service teachers in some disciplines was limited in the sample.

Studies focused on the components of the NOS can make it easier for people to acquire scientific literacy. This will help the number of pseudo-scientific beliefs prevalent in society to be reduced. Teachers and pre-service teachers play a significant role in this. In their study, Mıhlandız and Doğan (2017) concluded that inadequacies in the teaching of the NOS were due to low a level of self-efficacy. It can be recommended that the NOS should be taught as a separate course in teacher education programs. The history of pseudo-science also offers an ideal opportunity for teaching the NOS (Allchin, 2004). As well as attending to this recommendation in the literature, the results of this study suggest that a separate NOS course, including examples of the differences between pseudo-science and science, should be included in high school. In addition, the specific features, concepts and limits of science should be emphasized in this course. It was an expected result that science-related concepts and knowledge of the NOS that were independent of gender variables were more common in NSMT fields. However, basic education on the NOS should also be provided in SSAT subjects.

## References


Aarnio, K. & Lindeman, M. (2005). Paranormal beliefs, education, and thinking styles. *Personality and Individual Differences, 39*(7), 1227–1236. https://doi.org/10.1016/j.paid.2005.04.009

Abd-El-Khalick, F., Waters, M., & Le, A. (2008). Representations of nature of science in high school chemistry textbooks over the past four decades. *Journal of Research in Science Teaching*, *45*(7), 835-855. http://doi.org/10.1002/tea.20226

Abd-El-Khalick, F. (2005). Developing deeper understandings of nature of science: the impact of a philosophy of science course on preservice science teachers' views and instructional planning. *International Journal of Science Education, 27*(1), 15-42. http://doi.org/10.1080/09500690410001673810

Abd-El-Khalick, F. (2012). Nature of science in science education: toward a coherent framework for synergistic research and development. In B. J. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (pp. 1041-1060). Springer. https://doi.org/10.1007/978-1-4020-9041-7_69

Abd-El-Khalick, F. & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of Research in Science Teaching, 37*(10), 1057-1095. https://doi.org/10.1002/1098-2736(200012)37:10<1057::AID-TEA3>3.0.CO;2-C

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. https://doi.org/10.1080/09500690903055758

Ağlarcı, O. & Kabapınar, F. (2016). Developing prospective chemistry teachers' views of science and pseudoscience. *Amasya Education Journal, 5*(1), 248-286. https://doi.org/10.17539/aej.33301

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295–317. https://doi.org/10.1002/(SICI)1098-2736(200004)37:4<295::AID-

TEA2>3.0.CO;2-2

Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*(2), 194-213. https://doi.org/10.1002/tea.20099

Allchin, D. (2004). Pseudohistory and pseudo-science. *Science, & Education, 13*, 179–195. https://doi.org/10.1023/B:SCED.0000025563.35883.e9

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*(3), 518-542. https://doi.org/10.1002/sce.20432

Altındağ, C., Tunç Şahin, C., & Saka, Y. (2012). An example activity for teaching the nature of science. *Journal of Inquiry Based Activities (JIBA), 2*(1), 1-9. https://www.ated.info.tr/ojs-3.2.1-3/index.php/ated/article/view/81

American Association for the Advancement of Science (2007). *Atlas of science literacy* (Vol. 2). Oxford University Press. http://www.project2061.org/publications/atlas/sample/toc2.htm

Angın, D. E. & Özenoğlu, H. (2019). Perceptions of prospective teachers toward scientists. *Igdır University Journal of Social Sciences, 18*, 255-276. http://sosbilder.igdir.edu.tr/DergiTamDetay.aspx?ID=746&Detay=Ozet

Arı, U. (2010). *Investigation of the preservice science teachers' and preservice classroom teachers' views on nature of science*. [Unpublished master's thesis], Fırat University.

Aslan, O. (2009). *Science and technology teachers' views on nature of science and the reflexions of these views on classroom activities*. [Unpublished doctoral dissertation], Gazi University.

Aslan, O., Yalçın, N., & Tasar, M. F. (2009). The views of the teachers of the science and technology on the nature of science. *Ahi Evran University Faculty of Education Journal, 10*(3), 1-8. https://dergipark.org.tr/tr/download/article-file/1494009

Ayvacı, H. Ş. & Bağ, H. (2016). Investigating the views of primary school teacher candidates' for science pseudo-science distinction. *Amasya Education Journal, 5*(2), 539-566. http://doi.org/10.17539/aej.62204

Berger, R. & Hänze, M. (2015). Impact of expert teaching quality on novice academic performance in the jigsaw cooperative learning method. *International Journal of Science Education, 37*(2), 294–320. https://doi.org/10.1080/09500693.2014.985757

Beşli B. (2008). *The effect of analyzing sections of the history of science on pre-service elementary science teachers? views of the nature of science*. [Unpublished master's thesis]. Abant İzzet Baysal University.

Bunge, M. (2011). Knowledge: Genuine and bogus. *Science, & Education, 20*(5-6), 411–438. https://doi.org/10.1007/s11191-009-9225-3

Castelão-Lawless, T. (2002). *Epistemology of science, science literacy, and the demarcation criterion: The nature of science (NOS) and informing science (IS) in context.* Presentation in Informing Science, & IT Education Joint Conference: In SITE "Where Parallels Intersect", Cork, Ireland. https://doi.org/10.28945/2457

Çetinkaya, E. & Taşar, M. F. (2018). Development of pseudo-science belief scale (pbs): validity and reliability study. *Trakya Journal of Education, 8*(3), 497-512. http://doi.org/10.24315/trkefd.336650

Çetinkaya, E., Turgut, H., Duru, M. K., & Ercan, S. (2015). The first step in scientific literacy: improving students' academic knowledge in the context of science – pseudoscience demarcation. *Dicle University Ziya*

*Gökalp Faculty of Education Journal, 24*, 446-476. https://doi.org/10.14582/DUZGEF.546

Chen, S., Chang, W. H., Lieu, S. C., Kao, H. L., Huang, M. T., & Lin, S. F. (2013). Development of an empirically based questionnaire to investigate young students' ideas about nature of science. *Journal of Research in Science Teaching, 50*(4), 408–430. https://doi.org/10.1002/tea.21079

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science & Education, 15*(5), 463-494. https://doi.org/10.1007/s11191-005-4846-7

Clough, M. P. (2011). Teaching and assessing the nature of science: How to effectively incorporate the nature of science in your classroom. *The Science Teacher, 78*(6), 56-60. http://people.uncw.edu/kubaskod/SEC_406_506/documents/Teach_Assess_Nos.pdf

Cofré, H., Núñez, P. Santibáñez, D. Pavez, J. M., Valencia, M., & Vergara, C. (2019). A critical review of students' and teachers' understandings of nature of science. *Science & Education, 28*, 205–248. https://doi.org/10.1007/s11191-019-00051-3

Cortinas-Rovira, S., Alonso-Marcos, F., Pont-Sorribes, C., & Escriba-Sales, E. (2015). Science journalists' perceptions and attitudes to pseudo-science in Spain. *Public Understanding of Science, 24*(4), 450–465. https://doi.org/10.1177/0963662514558991

Dagher, Z. R. & Erduran, S. (2016). Reconceptualizing the Nature of Science for Science Education. *Science & Education, 25*, 147–164. https://doi.org/10.1007/s11191-015-9800-8

Demir, N. & Akarsu, B. (2013). Perceptions of secondary school students about the nature of science. *Journal of European Education, 3*(1), 39-51. http://www.eu-journal.org/index.php/JEE/article/view/191

Doğan Bora, N. (2005). *Investigating science teachers' and high school students' views on the nature of science in Turkey*. [Unpublished doctoral dissertation]. Gazi University.

Emran, A., Spektor-levy, O., Tal, O. P., & Assaraf, O. B. Z. (2020). Understanding students' perceptions of the nature of science in the context of their gender and their parents' occupation. *Science & Education, 29*, 237–261. https://doi.org/10.1007/s11191-020-00103-z

Erdaş Kartal, E. & Ada, E. (2018). Understandings of preschool teacher candidates about nature of science. *Cumhuriyet International Journal of Education, 7*(1), 84–101 https://doi.org/10.30703/cije.384055

Erdoğan, R. (2004). *Investigation of the preservice science teachers' views on nature of science*. [Unpublished master's thesis], Middle East Technical University.

Erduran, S., & Dagher, Z. R. (2014). Reconceptualizing nature of science for science education. In *Reconceptualizing the nature of science for science education* (pp. 1-18). Springer. https://doi.org/10.1007/978-94-017-9057-4_1

Field, A. (2013) *Discovering Statistics Using IBM SPSS Statistics.* (4th Edition), Sage.

Fredricks, J. A., Hofkens, T., Wang, M. T., Mortenson, E., & Scott, P. (2018). Supporting girls' and boys' engagement in math and science learning: a mixed methods study. *Journal of Research in Science Teaching, 55*(2), 271–298. https://doi.org/10.1002/tea.21419

Gecewicz, C. (2018). *'New Age' beliefs common among both religious and nonreligious Americans.* Pew Research Center. https://pewrsr.ch/2NR7Bme

George, D. & Mallery, M. (2010). *SPSS for Windows step by step: a simple guide and reference, 17.0 update.* (10a ed.) Pearson.

Good R. (2012). Why the study of pseudoscience should be included in nature of science studies. In Khine M. (eds). A*dvances in nature of science researc*h. Springer. https://doi.org/10.1007/978-94-007-2457-0_5

Gray, T. (1984). University course reduces belief in the paranormal. *The Skeptical lnquirer, 8*, 247-251.

Greaves-Fernandez, N. (2010). *Influence of views about the nature of science indecision-making about socio-scientific and pseudo-scientific issues*. [Unpublished doctoral dissertation], The University of York.

Gül, Ş. (2016). Prospective biology, physics and chemistry teachers' conceptions towards science-pseudoscience distinction. *Journal of Theoretical Educational Science, 9*(2), 177-197.

Güneş, B. (2003). In the light of the paradigma concept the structure of the scientific revolution and science wars: from the physicist's front Thomas S. Kuhn and Alan D. Sokal. *The Journal of Turkish Educational Sciences (JTES), 1*(1), pp.20. https://dergipark.org.tr/tr/pub/tebd/issue/26133/275257

Gürel, Z. (2002). *Ways of art students understanding the nature of science*. Presentation at 5th National Science and Mathematics Education Congress, Ankara, Turkey. https://docplayer.biz.tr/12307904-Resim-bolumu-ogrencilerinin-fen-biliminin-dogasini-anlama-bicimleri.html

Gürgil, F. (2019). An analysis of the discrimination made by preservice social studies teachers between science and pseudoscience. *Journal of History School, 42*, 965-984. https://doi.org/10.29228/joh.30213

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., & Tatham, R. L. (2013). *Multivariate data analysis*. Pearson Education Limited.

Hanuscin, D., Akerson, V., & Phillipson-Mower, T. (2006). Integrating nature of science instruction into a physical science content course for preservice elementary teachers: NOS views of teaching assistants, *Science Education, 90*(5), 912-035. https://doi.org/10.1002/sce.20149

Irez, S. (2006). Are we prepared?: An assessment of preservice science teacher educators' beliefs about nature of science. *Science Teacher Education, 90*(6), 1113-1143. https://doi.org/10.1002/sce.20156

Irez, S. (2008). Nature of science as depicted in Turkish biology textbooks. *Science Education, 93*(3), 422-447. https://doi.org/10.1002/sce.20305

Irzik, G. & Nola, R. (2011). A family resemblance approach to the nature of science for science education. *Science & Education, 20*(7), 591-607. https://doi.org/10.1007/s11191-010-9293-4

Jackson, S.L. (2011). *Research Methods and Statistics: A Critical Approach*, (4th edition). Cengage Learning.

Kampourakis, K. (2016). The "general aspects" conceptualization as a pragmatic and effective means to introducing students to nature of science. *Journal of Research in Science Teaching, 53*(5), 667-682. https://doi.org/10.1002/tea.21305

Keranto, T. (2001). The perceived credibility of scientific claims, paranormal phenomena, and miracles among primary teacher students: A comparative study. *Science & Education, 10*, 493–511. https://link.springer.com/article/10.1023/A:1011261132355

Kızılcık, H. Ş. (2021). Does binding energy bind? *Physics Education, 56*(3), 033005, pp.3. https://doi.org/10.1088/1361-6552/abe5b7

Kızılcık, H. Ş., Temiz, B. K., Tan, M., & İngeç, Ş. K. (2007). A study of verbal section teacher candidates' attitude towards science, science education and technology. *Eğitim ve Bilim - Education and Science, 32*(146), 80-88. http://egitimvebilim.ted.org.tr/index.php/EB/article/view/750/148

Kirman-Çetinkaya, E. & Laçin-Şimşek, C. (2012, June). *Knowledge levels of prospective teachers regarding scientific method: Science-pseudo-science distinction.* Presentation in 10th National Science and

Mathematics Education Congress, Niğde, Turkey.

Kirman-Çetinkaya, E., Laçin-Şimşek, C., & Çalışkan, H. (2013). The adaptation study of science and pseudo-science distinction. *Trakya University Journal of Education, 3*(2), 31-43. https://dergipark.org.tr/tr/pub/trkefd/issue/21474/230165

Köseoğlu, F., Tümay, H., & Üstün, U. (2010). Developing a professional development package for nature of science instruction and discussion about its implementation for pre-service teachers. *Ahi Evran University Faculty of Education Journal, 11*(4), Special Issue, 129-162.

Küçük, M. (2008). Improving preservice elementary teachers' views of the nature of science using explicit-reflective teaching in a science, technology and society course. *Australian Journal of Teacher Education, 33*(2). https://doi.org/10.14221/ajte.2008v33n2.1

Landau, S. & Everitt, B. S. (2004). *A handbook of statistical analyses using SPSS*. Chapman & Hall/CRC Press LLC.

Leblebicioğlu, G., Çapkınoğlu, E., Metin Peten, D., & Schwartz, R. S. (2020). Views of nature of scientific inquiry of students in different high schools. *Education and Science, 45*(201), 143-165. http://egitimvebilim.ted.org.tr/index.php/EB/article/view/7911/3040

Leblebicioğlu, G., Metin, D., & Yardımcı, E. (2012). Effect of science workshop on science and mathematics teachers' views of the nature of science. *Education and Science, 37*(164), 57-70. http://egitimvebilim.ted.org.tr/index.php/EB/article/view/362/363

Lederman, N. G., Bartos, S. A., Lederman J. S. (2014) The development, use, and interpretation of nature of science assessments. In Matthews M. (Ed), *International Handbook of Research in History, Philosophy and Science Teaching* (pp. 971-997). Springer. https://doi.org/10.1007/978-94-007-7654-8_29

Lederman, N. G. (2007). Nature of Science: Past, Present, and Future. In Abell S. K. and Lederman, N. G. (Eds.), *Handbook of Research on Science Education*. Lawrence Erlbaum Associates.

Lederman, N. G. & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (Vol. II, pp. 600-620). Routledge.

Lindeman, M. (1998). Motivation, cognition and pseudo-science. *Scandinavian Journal of Psychology, 39*, 257–265. https://doi.org/10.1111/1467-9450.00085

Lundström, M., & Jakobsson, A. (2009). Students' ideas regarding science and pseudo-science in relation to the human body and health. *Nordic Studies in Science Education. 5*(1), 3- 15. https://doi.org/10.5617/nordina.279

Makarova, E. & Herzog, W. (2015). Trapped in the gender stereotype? The image of science among secondary school students and teachers. *Equality, Diversity and Inclusion: An International Journal, 34*(2), 106–123. https://doi.org/10.1108/EDI-11-2013-0097

Matthews, M. R. (2012). Changing the focus: From nature of science (NOS) to features of science (FOS). In M. S. Khine (Ed.), *Advances in nature of science research, concepts and methodologies* (pp. 3-26). Springer. https://doi.org/10.1007/978-94-007-2457-0_1

McComas, W. F., Clough, M. P., & Almazroa, H. (2000). The role and character of the nature of science in science education. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 3-39). Kluwer Academic Publishers. https://doi.org/10.1007/0-306-47215-5_1

McComas, W. F. (2010). The history of science and the future of science education. In P. V. Kokkotas, K. S.Malamitsa, & A. A. Rizaki (Eds.), *Adapting Historical Knowledge Production to the Classroom* (pp. 37-53), Springer.

Mencken, F. C., Bader, C. D., & Stark, R. (2008). Conventional Christian beliefs and experimentation with the paranormal. *Review of Religious Research, 50*, 194–205. https://www.baylorisr.org/wp-content/uploads/2019/11/stark_conventional-1.pdf

Mencken, F. C., Bader, C. D., & Kim, Y. J. (2009). Round trip to hell in a flying saucer: the relationship between conventional Christian and paranormal beliefs in the United States. *Sociology of Religion, 70*, 65–85. https://doi.org/10.1093/socrel/srp013

Mesci, G. (2016). *Preservice science teachers' pedagogical content knowledge for nature of science and nature of scientific inquiry: A successful case study*. [Unpublished doctoral dissertation], Western Michigan University.

Mesci, G. & Schwartz, R.S. (2017). Changing pre-service science teachers' views of nature of science: Why some conceptions may be more easily altered than others?, *Research in Science Education, 47*, 329–351. https://doi.org/10.1007/s11165-015-9503-9

Mıhlandız, G. & Doğan, A. (2017). Investigation of the pre-service science teachers' pedagogical content knowledge about the nature of science. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi (H. U. Journal of Education), 32*(2), 380-395.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science!: Putting research to work in K-8 classrooms*. National Academies Press.

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

National Research Council (2012). *A framework for K-12 science education: practices, crosscutting concepts, and core ideas*. National Academy Press.

National Science Board (2006). *Science and engineering indicators - 2006*. National Science Foundation Press.

Nehring, A., Nowak, K. H., zu Belzen, A. U., & Tiemann, R. (2015). Predicting students' skills in the context of scientific inquiry with cognitive, motivational, and sociodemographic variables. *International Journal of Science Education, 37*(9), 1343–1363. https://doi.org/10.1080/09500693.2015.1035358

Niaz, M. (2010). Science curriculum and teacher education: The role of presuppositions, contradictions, controversies and speculations vs Kuhn's 'normal science'. *Teaching and Teacher Education, 26*(4), 891-899. https://doi.org/10.1016/j.tate.2009.10.028

Norris, S. P. & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224-240. https://doi.org/10.1002/sce.10066

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "ideas-about science" should be taught in school science? A Delphi study of the expert community. *Journal of Research in Science Teaching, 40*, 692-720. https://doi.org/10.1002/tea.10105

Özcan, I. (2011). *Development of an instrument for the nature of science beliefs and identifying of the nature of science believing of pre-service science teachers*. [Unpublished master's thesis], Marmara University.

Özcan, I. & Turgut, H. (2014). Assessing preservice science teachers' nature of science understanding: a study of scale development. *Sakarya University Journal of Education, 4*(2), 38-56. https://doi.org/10.19126/suje.93713

Pavić, Ž. (2013). Science and pseudo-science in postmodern societies. *Informatologia, 46*(2), 145–153.

Peltzer, K. (2003). Magical thinking and paranormal beliefs among secondary and university students in South Africa. *Personality and Individual Differences, 35*, 1419–1426. https://doi.org/10.1016/S0191-8869(02)00359-8

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. https://doi.org/10.1080/09500690050166724

Qtait, M., Abu Liel, F., Massad, S., & Asfour, A. (2021). Why patients use traditional medicine in burn. *International Journal of Innovative Research in Medical Science (IJIRMS)*, 6(11), 840-844. https://doi.org/10.23958/ijirms/vol06-i11/1272

Richardson, J. T. E. (2011). Eta squared and partial eta squared as measures of effect size in educational research. *Educational Research Review, 6*, 135–147. https://doi.org/10.1016/j.edurev.2010.12.001

Rudge, D. W., Cassidy, D. P., Fulford, J. M., & Howe, E. M. (2014). Changes observed in views of nature of science during a historically based unit. *Science & Education, 23*(9), 1879-1909. https://doi.org/10.1007/s11191-012-9572-3

Saka, M. & Sürmeli, H. (2017). Preservice science teachers' use of NOS in pseudoscientific scenarios. *Trakya Journal of Education, 7*(2), 504-525. https://doi.org/10.24315/trkefd.305999

Saraç, E. & Cappellaro, E. (2015). Views of the elementary teachers and pre-service elementary teachers on the nature of science. *Mediterranean Journal of Humanities, 2*, 331-349. https://doi.org/10.13114/MJH.2015214576

Schizas, D., Psillos, D., & Stamou, G. (2016). Nature of science or nature of the sciences? *Science Education, 100*, 706-733. https://doi.org/10.1002/sce.21216

Schwartz, R.S., Akom, G., Skjold, B., Hong, H. H., Kagumba, R., & Huang, F. (2007). *A change in perspective: Science education graduate students' reflections on learning about NOS*. Presentation at NARST, April 15-18, New Orleans, LA.

Şenler, B. & İrven, Ö. (2016). Primary pre-service teachers' epistemological beliefs and pseudoscientific beliefs. *Mersin University Journal of the Faculty of Education, 12*(2), 659-671. https://doi.org/10.17860/efd.25364

Seung, E., Bryan, L., & Butler, M. (2009). Improving preservice middle grades science teachers' understanding of the nature of science using three instructional approaches. *Journal of Science Teacher Education, 20*(2), 157-177. https://doi.org/10.1007/s10972-009-9130-2

Shein, P. P., Li, Y. Y., & Huang, T. C. (2014). Relationship between scientific knowledge and fortune-telling. *Public Understanding of Science, 23*(7) 780– 796. https://doi.org/10.1177/0963662514522169

Shermer, M. (2002). *Why people believe weird things: Pseudoscience, superstition, and other confusions of our time*. Freeman and Company.

Silva, T. & Woody, A. (2022). Supernatural sociology: Americans' beliefs by race/ethnicity, gender, and education. *Socius*, 8, 1–18. https://doi.org/10.1177/23780231221084775

Sjödin, U. (2002). The Swedes and the paranormal. *Journal of Contemporary Religion, 17*(1), 75-85, https://doi.org/10.1080/13537900120098174

Snow, C. & Collini, S. (2012). *The Two Cultures* (Canto Classics). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139196949

Tabachnick, B. G. & Fidell, L.S. (2013). *Using multivariate statistics* (6th edition) Pearson.

Taber, K. (2017). The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Reserch in Science Education, 48*, 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tatar, E., Karakuyu Y., & Tüysüz C. (2011). Pre-service primary school teachers' misunderstandings about nature of science. *Buca Faculty of Education Journal, 29*, 153-161.

Topdemir, H. G. & Unat, Y. (2019). *History and Philosophy of Science*. Pegem Akademi Press.

Tseng, Y. C., Tsai, C. Y., Hsieh, P. Y., Hung, J. F,, & Huang, T. C. (2014). The relationship between exposure to pseudo-scientific television programmes and pseudo-scientific beliefs among Taiwanese university students. *International Journal of Science Education, Part B, 4*(2), 107-122. https://doi.org/10.1080/21548455.2012.761366

Tufan, E. (2007). Music teacher candidates' views about nature of scientific knowledge. *Journal of Gazi Educational Faculty, 27*(3), 99-105. https://dergipark.org.tr/tr/pub/gefad/issue/6749/90741

Turgut, H. (2007). Scientific literacy for all. *Ankara University Journal of Faculty of Educational Sciences, 40*(2), 233-256. https://doi.org/10.1501/Egifak_0000000176

Turgut, H. (2009). Pre-service science teachers' perceptions about demarcation of science from pseudoscience. *Education and Science, 34*(154), 50-69. http://egitimvebilim.ted.org.tr/index.php/EB/article/view/548/36

Turgut, H., Akçay, H., & Irez, S. (2010). The impact of the issue of demarcation on pre-service teachers' beliefs on the nature of science. *Educational Sciences: Theory, & Practice, 10*(4), 2621-2663. https://files.eric.ed.gov/fulltext/EJ919885.pdf

Türk, C., Yıldırım, B., Bolat, M., & Ocak İskeleli, N. (2018). Opinions of preservice pre-school teachers on the nature of science. *Anemon Journal of Social Sciences of Mus Alparslan University, 6*(STEMES'18), 115-121. https://doi.org/10.18506/anemon.471414

Uçar, M. B., & Şahin, E. (2018). Pre-service science teachers' discrimination level of science and pseudo-science. *Science Education International, 29*(4), 267-273.

Ürey, M., Karaçöp, A., Göksu, V., & Çolak, K. (2017). Science perceptions of pre-service teachers based on science and social sciences. *YYU Journal of Education Faculty, XIV*(I), 205-226. https://doi.org/10.23891/yyuni.2017.8

Uyar, T. (2016). Astrology pseudoscience and a discussion about its threats to society. *Journal of Higher Education and Science, 6*(1), 50-60. https://doi.org/10.5961/jhes.2016.142

Williams, C. T. & Rudge, D. W. (2019). Effects of historical story telling on student understanding of nature of science. *Science & Education, 28*, 1105-1133. https://doi.org/10.1007/s11191-019-00073-x

Williams, E., Francis, L.J., & Robbins, M. (2007). Personality and paranormal belief: A study among adolescents. *Pastoral Psychology, 56*, 9-14. https://doi.org/10.1007/s11089-007-0094-x

Wilson, J. A. (2018). Reducing pseudoscientific and paranormal beliefs in university students through a course in science and critical thinking. *Science & Education*, *27*, 183–210. https://doi.org/10.1007/s11191-018-9956-0

Woods, P. J. (1984). Evidence for the Effectiveness of a reading program in changing beliefs in the paranormal. *The Skeptical Inquirer, 9*(1), 67-70. https://skepticalinquirer.org/1984/10/evidence-for-the-effectiveness-of-a-reading-program/

Yalçın S. A. & Yalçın S. (2011). Analyzing elementary teachers' views on the nature of science according to their academic levels. *Procedia Social and Behavioral Sciences, 15*, 942-946. https://doi.org/10.1016/j.sbspro.2011.03.217

Yalvaç, B. & Crawford, B. (2002). *Eliciting prospective science teachers' conceptions of the nature of science in Middle East Technical University (METU), in Ankara*. Paper presented at the annual meeting of the Proceedings of the 2002 Annual International Conference of the Association for the Education of Teachers in Science (pp. 228-266), Pensacola, FL. Association for the Education of Teachers in Science (ERIC Document Reproduction Service No. ED 465 602). http://files.eric.ed.gov/fulltext/ED465602.pdf

Yardımcı, A. B. (2019). Science and pseudo-science: a social criterion for determining the nature of scientific community and demarcating pseudo-science. *Kaygı, 18*(II), 567-588. http://doi.org/10.20981/kaygi.622834

Yenice, N., Özden, B., & Hiğde, E. (2017). Examination of middle school students' metacognition and views of nature of science according to gender and science achievement. *OMU Journal of Education Faculty, 36*(2), 1-18. https://dergipark.org.tr/en/pub/omuefd/issue/33619/373025

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## Appendix

**Scale 1: Pseudo-scientific Beliefs Scale (PSBS)**

1. Some people can transfer their thoughts to another person with the power of their minds.
2. Some people can move objects with the power of their minds.
3. Flying vehicles from other planets come to visit the Earth.
4. When the mind is sufficiently focused, objects can be levitated.
5. Extraterrestrials visit the Earth.
6. It is possible to design machines that can produce infinite energy when you start.
7. It is possible to bend metal objects such as spoons from afar with just the power of the mind, without applying physical force.
8. Structures such as the pyramids were built by beings who visited the Earth in ancient times.
9. Some people have the ability to see what's going on in remote areas without leaving where they are.
10. It is possible to predict the gender of an unborn baby by dangling the wedding ring of the pregnant women from a piece of string or rope.
11. Horoscopes are based on science.
12. Some people can accurately tell a person's future by looking at the palm of their hand.
13. Fortune-telling and predicting the future are based on science.
14. Some numbers can that bring luck to people.
15. A person's future can be accurately determined by observing celestial bodies.
16. A polygraph is a technological tool that gives precise results and is based on sound scientific foundations.
17. There are many effective treatment methods that doctors do not use.
18. It is possible to cure certain diseases by massaging specific areas of the soles of the feet.
19. It is possible to identify diseases by examining the strength or weakness of the muscles.
20. It is possible to treat cancer in non-medical ways.
21. Each of the organs in the body is associated with certain areas on the soles of the feet.

**Scale 2: Nature of Science Beliefs Scale (NOSBS)**

1. If knowledge is scientific, it has been proven definitively and is no longer subject to change.
2. A student who says "The object I released fell to the ground" is expressing an observation they have made.
3. There is only one scientific method that scientists follow in order.
4. Scientists use their creativity and imagination to reach conclusions from the data they have.
5. Science deals only with directly observable events.
6. Science is dependent on social values (political, religious, philosophical, etc.) and is affected by these values as it develops.
7. Science is based on the assumption that the workings of nature can be understood.
8. Even if scientific research is done correctly, the information obtained as a result of this research may change in the future.

9. If different scientists have the same data, they will reach the same conclusion.
10. Scientific theories are explanations based on specific assumptions about entities that cannot be observed directly.
11. After scientific theories are proven and accepted by scientific circles, they turn into scientific laws.
12. The personal feelings and thoughts of scientists do not affect the results they reach in their studies.
13. A student who determines that nitrogen gas has the properties of compression and expansion, is expressing an observation when they say, "Nitrogen gas has a void structure".
14. Scientific laws are scientific claims that have been conclusively proven.
15. If a conclusion has been reached through scientific experiments, this conclusion is absolutely correct.
16. Science cannot answer all questions about human life.
17. Creativity and imagination are also used in scientific studies.
18. Scientific studies are influenced by the cultures and value judgments of societies.
19. Different scientific methods are used in different branches of science.
20. Scientists are now absolutely sure of the cell theory they have developed.
21. A student who says that the object he releases "falls due to the force of gravity" is expressing an observation.
22. A claim that cannot be directly tested cannot be scientific.
23. As new scientific theories are put forward; scientists can change their claims by reinterpreting the data they have.
24. Scientists use their creativity and imagination only when designing their experiments.
25. A student who says, "When you hold a metal spoon to a heat source, it gets hot" is expressing an observation.
26. Science is based on the assumption that scientific laws apply equally throughout the universe.
27. Scientific theories are used to explain the phenomena covered in scientific laws.
28. Science can find answers to all the questions we can think of.
29. Science consists of the systematic observation of entities, events and processes.
30. Scientific knowledge changes only as technology develops.
31. Scientific theories can be tested directly.
32. To reach the right result in scientific research, the steps of determining the problem, collecting data, forming a hypothesis and experimenting should be followed in order.
33. To be successful, scientists act without prejudice (religious, cultural, philosophical, etc.) and work independently of personal values.
34. Only natural factors are included in scientific explanations, supernatural powers (God, angels, etc.) are not mentioned.
35. A scientific theory attempts to explain the cause of certain events.
36. Supernatural beings such as genies and angels cannot be the subject of science.
37. Creativity is required to create explanations such as the orbits and energy levels in the "Bohr Model of the Atom".