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Perceptions of Eighth Graders Concerning the Aim, Effectiveness, and Scientific Basis of Pseudoscience: the Case of Crystal Healing

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Abstract Practices such as astrology or crystal healing can be defined as pseudoscience. Against pseudoscience, one of the major responsibilities of science education must be to develop science-literate individuals who are able to understand what science is, how science is undertaken, how scientific knowledge is constructed, and how it is justified, then they will be able to determine whether a claim is valid and be alert to practices which fall outside the realms of science, especially those in the area of pseudoscience. For this reason, the ability of recognizing flawed process and claims of pseudoscience is referred to one of the crucial parts of science literacy. The present study aimed to uncover middle school students' understanding of the inherent aim of pseudoscientists and pseudoscientific applications related to crystals and to reveal their judgments and justifications regarding the effectiveness and scientific basis of these applications. The present study was qualitative in nature. The results of the study showed that the students were very gullible about the aim, effectiveness, and scientific basis of pseudoscientific practices and in particular the use of crystals. Furthermore, similar to pseudoscientists, the students generally used weak reasoning to evaluate the presented claims and research designs about crystals and crystal healing.

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Introduction

Most countries are pursuing the aim of developing responsible citizenship in their society and in this context; science literacy is a vital attribute of being a responsible citizen. The primary goal of science education is to educate students about both the scientific knowledge of the physical world and the ways that science generates scientific knowledge based on data and evidence. Thus, one of the major issues in science education is to train scientifically literate individuals who are able to understand what science is, how science is undertaken, and how scientific knowledge is constructed and justified. In addition to this, one of the major indicators of science literacy is a capacity to distinguish science from pseudoscience. Hurd (1998) emphasized the skeptical nature of science literacy when he defines a scientifically literate person as someone who "distinguishes theory from dogma, and data from myth and folklore, distinguishes science from pseudoscience such as astrology, quackery, the occult, and superstition, and distinguishes evidence from propaganda, fact from fiction, sense from nonsense, and knowledge from opinion" (p. 413). In daily life, there are a multitude of television programs, advertisements, internet websites, and social media pages that describe how the position of the planets influence people's characteristics and future life, or discuss the features of the gemstones that are presumed to heal various diseases and illnesses. In this context, people need to learn to critically assess these pseudoscientific claims and practices which can have a serious impact on their life, health, and even their financial affairs. In this respect, people's understanding of the aspects of scientific knowledge and science itself, and their difference from other ways of knowing, would help them in criticizing the knowledge proposed by sources such as pseudoscientific contexts and advertisement, then they will be able to determine whether a claim is valid and be alert to practices which fall outside the realms of science, especially those in the area of pseudoscience. Although science literacy entails "being able to deploy some robust criteria of demarcation in order to distinguish between good science and bad science, detect error, bias and fraud, and recognize pseudoscience and non-science masquerading as science" (Hodson 2011, p. x), research studies have consistently revealed that students are unable to demarcate science and pseudoscience (DeRobertis & Delaney 1993, 2000; Martin 1994; NSB 2002, 2008, 2012; Preece & Baxter 2000; Sugarman et al. 2011). How do students make meaning of pseudoscience? What are their attributions and argumentations about pseudoscience and pseudoscientific applications, which make them vulnerable to pseudoscience? This study is about students' pseudoscientific beliefs and their attributions to pseudoscience in terms of aim, effectiveness, and scientific basis of pseudoscientific applications. The main focus of the study is to reveal middle school students' understanding of the inherent aim of pseudoscientists and pseudoscientific applications, and their judgments and justifications regarding the effectiveness and scientific basis of these applications. This study is organized as follows. The first section discusses the necessity of making room for the demarcation of science and pseudoscience in light of the empirical evidence coming from related literature. Specifically, the section unpacks why science educators should take students' pseudoscientific beliefs and their related attributions seriously in terms of science literacy. The second section describes what pseudoscience is. The third section elaborates the rationale of the study, and the fourth section examines middle school students' understanding of the inherent aim of pseudoscientists and pseudoscientific applications, and their judgments and justifications regarding the effectiveness and scientific basis of these applications, and provides empirical data about students' attributions and argumentations about pseudoscience and pseudoscientific applications.

The Necessity of Making Room for the Demarcation of Science and Pseudoscience

People read or hear scientific, pseudoscientific, and even superstitious arguments and explanations about phenomena throughout their life from their teachers, relatives, friends, and mass media. Increase in access to various kinds of information in new media environments increases the opportunities for public access to misinformation or people engaging in fraud and presuming expertise outside their areas of competence as well as trustworthy scientific information (Snow & Dibner 2016). Science education is referred to as a vital stakeholder "to promote a culture of scientific thinking and inspire citizens to use evidence-based reasoning for decision making" (European Commission 2015, p. 14) in the context of new media environment. Nevertheless, the issue of pseudoscience is an important but neglected aspect of science education. One of the main reasons for believing in pseudoscientific issues is given as the poor quality of science education (Carroll 2005; Ede 2000; Moore 1992; Walker et al. 2002). Realizing and critically evaluating pseudoscience is not included in most science curricula or science education reform documents (European Commission 2011; MoNE 2013; NGSS 2013; NSES 1996). However, most researchers have stated that the ability of recognizing the flawed process and claims of pseudoscience should be considered as part of science literacy (Ede 2000; Good & Slezak 2011; Hodson 2011; Martin 1994; Mugaloglu 2014). For instance, Martin (1994) suggested that the goal of science education is to be scientific rather than understanding science and to help students "think and act in a scientific manner in their daily life" and, continued by stating, "learning to think critically about pseudoscientific and paranormal beliefs is part of being scientific" (Martin 1994, p. 357). Similarly, Ede (2000) proclaimed the deficiency of science education in achieving science literacy. By criticizing the absence of a significant drop in irrationality, which is supposed to be as a result of a significant increase in general science education, he reasoned out that "if students leave science class with no understanding of how scientific ideas were actually arrived at, or why science was done, it is not difficult to understand why many are susceptible to pseudoscience" (p. 50). In the same way, Good and Slezak (2011) stressed the demarcation problem in science literacy by asking the question of "whether people be considered as scientifically literate if they are unable to recognize common forms of pseudoscience" (p. 401).

To date, researchers who have addressed science literacy have mostly referred to the ability of recognizing pseudoscientific claims and beliefs as a precursor of being science literate. The assumption underlying these views is that science illiteracy can increase the beliefs in pseudoscience and irrationality. On the other hand, some researchers have approached the issue from a different perspective. For instance, Beyerstein (1995) underlined the importance of social environment, in which information is delivered and maintained by stating, "the climate in which pseudosciences thrive contributes to a decline in science literacy and critical thinking" (p. 42). Accordingly, decreased science literacy constrains citizens from being responsible decision-makers concerning policies. In addition, Moore (1992) demonstrated a clear relationship between pseudoscientific beliefs and a lack of critical thinking ability by claiming that "the popularity of astrology and similar pseudoscientific shams attest to the unwillingness or inability of many people to think critically" (p. 4). In this respect, it necessitates understanding the science literacy in terms of citizen science, citizenship-based science literacy, or cultural activity. Science should be considered as collective action than individual efforts (Roth & Calabrese Barton 2004; Roth & Lee 2004). Roth and Lee (2004) proposed to think about science literacy as a characteristic of certain everyday situations ranging from personal matters to activism or organized protest. Pseudoscience, quackery, occult, and superstition are also challenges that need to be handled by the people in society, as well as the other problems such as making decisions about socio-scientific issues, finding sustainable energy sources, or choosing the best farming practice. In this manner, education should prepare people to critically assess different kinds of assertions and claims, to search for evidence and to differentiate strong arguments from [pseudoscientific] arguments (AAAS 1989). Clearly, it should not be supposed that science education automatically develops learners to be able to think critically and evaluate pseudoscientific claims which imitate basic principles of science; furthermore, the emphasis on the nature of science itself does not guarantee that learners will be less likely to believe in pseudoscience (Good 2009). For this reason, pseudoscientific beliefs and claims, and the increase in pseudoscientific beliefs, should be a concern of science educators and learning how to realize and evaluate the flawed process and claims of pseudoscience should be a part of science education (Ede 2000; Good 2012; Lundström & Jakobsson 2009; Martin 1994; Preece & Baxter 2000; Walker et al. 2002).

In terms of relationship between pseudoscientific belief and the understanding of scientific concepts, Johnson (2003) addressed the relationship among science factual knowledge, conceptual understanding of science, and belief in pseudoscience by comparing science majors and non-science majors. According to his results, there was no apparent relationship between pseudoscientific belief and the understanding of scientific concepts. Similarly, Walker et al. (2002) administered a questionnaire to 207 American undergraduates from three different universities. They structured their research based on whether science learning lead to skepticism about pseudoscience, and they found no relation between level of science knowledge and skepticism regarding pseudoscientific beliefs. They also stated that "it is possible for a student to accumulate fairly sizable science knowledge without learning how to properly distinguish between reputable science and pseudoscience" (p. 24). For this reason, it is necessary to make room in the science curricula for learning to realize and critically evaluating pseudoscience. In a pedagogical manner, we need to give specific place to the demarcation issue and design an explicit way to teach students how to think and criticize pseudoscientific claims. Pseudoscience should be handled in an explicit way in science education. Good (2009) suggested some reasons for why space should be made in the science curriculum for the study of pseudoscience: "First, belief in pseudoscience continues to be a widespread problem in the 21st century even though science has been a dominant force in the U.S. and other countries for well over 50 years. Second, having pseudoscientific examples to study along with positive examples of science should help students better understand the nature of science (NOS) as well as the nature of pseudoscience (NOPS). Third, studying NOPS as a part of studying NOS should help students think more about their own beliefs and how they develop" (pp. 7–8).

What Is Pseudoscience?

There is no clear-cut checklist that summarizes the key characteristics of pseudoscience in order to grasp what pseudoscience is. Nevertheless, there have been attempts to differentiate the bogus side of pseudoscience. For instance, in their paper on skepticism and gullibility, Preece and Baxter (2000) defined pseudoscience as "a set of ideas or theories which are claimed to be scientific but which are contrary to standard science and which have failed empirical tests or which cannot in principle be tested." (p. 1148). Beyerstein (1995) described pseudoscience as "fields that try to appropriate the prestige of genuine sciences, and copy their outward trappings and protocols, but fall far short of acceptance standards of practice and verification in the legitimate fields they seek to emulate" (p. 3). The pretention of being science as a characteristic of pseudoscience has been emphasized by many researchers (Bunge 2011; Carroll 2014; Green 1996; Lilienfeld & Landfield 2008; Mugaloglu 2014; Shermer 1997). Another characteristic of a pseudoscientific claim is its proponents who insist on the idea that it is scientific or display their attempts as science (Carroll 2005; Eve & Dunn 1990; Hansson 2015). In order to clarify this issue, Hansson (1996) presented two criteria that should be satisfied in order to be called pseudoscience, "it is not scientific"; yet, "its major proponents try to create the impression that it is scientific" (p. 169). In addition, Lilienfeld et al. (2001) emphasized the non-realistic persistence of adherents by stating that "What renders these claims largely or entirely pseudoscientific is not that they are necessarily incorrect, but rather that their proponents have typically insisted that they are correct, despite compelling evidence to the contrary" (p. 183).

Although science and pseudoscience seem to have some similarities, they are absolutely different in their assumptions, processes, and methods. Popper (1963) proposed the falsification criterion and stated that the criterion of the scientific status of a theory depends on its falsifiability, refutability, and testability. Many philosophers and researchers pursued Popper's criterion of falsification (Baran et al. 2014; Beyerstein 1995; Carroll 2014; Hansson 2015) in terms that with a basic definition, a hypothesis is falsifiable "if it can potentially be ruled out by data to show that hypothesis does not explain the observations" (Baran et al. 2014, p. 24). Beyerstein (1995) defended falsificationism by stating that "a growing accumulation of instances supporting a theoretical explanation can only strengthen our subjective probability that the theory is correct, but a single disconfirming instance is sufficient to topple the entire enterprise" (p. 30). Popper argued that all science is based on hypotheses and emphasized the hypothesis testing in scientific method. However, "scientific investigations involve asking and answering a question and comparing the answer with what scientists already know about the world" (NRC 2000). Hypothesis testing would be useful in some cases, but all scientific investigations do not necessarily state and test a hypothesis (Lederman et al. 2014). For this reason, there are some objections to falsificationism. Mahner (2013) criticized Popper's falsifiability condition as not having the ability to detect all possible problems of areas which are not labeled as science. Specifically, he pointed out the problem that "many pseudosciences do contain falsifiable statements and therefore would count as sciences" giving example of astrology (p. 30). Most of the statements related to astrology are statistically testable and refutable, which means that it is falsifiable; however, it is not scientific due to not fulfilling other requirements.

Eve and Dunn (1990) made a clear definition of pseudoscience by stressing the methodological errors in pseudoscience referring to beliefs which "lack empirical support or were arrived at either through faulty reasoning or poor scientific methodology" (Eve & Dunn 1990,

p. 10), which can be definitively labeled as pseudoscientific. Similarly, Smith (2010) differentiated pseudoscience in that it uses methodology in which sources, logic, and observations are used erroneously; thus, it "fails to systematically consider alternative explanations" (p. 38). Emphasizing the methodological errors in pseudoscience, Lawson (2007) stated that pseudoscience is "false or sham science that is not characterized by carefully controlled studies that result in publicly verifiable knowledge" (p. 4). Moreover, other methodological insufficiencies of pseudoscience were emphasized by Ladyman (2013), who referred to pseudoscience as "cult figures and networks whose relational structure involves a lot of chat, but lacks the integration with rich mathematics, material interventions, and technology that characterizes science" (pp. 56–57).

Furthermore, there has been criticism of pseudoscience with respect to its methodological structure. For instance, Carroll (2005) highlighted the scientific method of testing and evaluating claims and criticized the pseudoscience as misunderstanding, misusing, misapplying, or ignoring scientific method of testing and evaluating claims. Additionally, Carroll (2005) provided three basic criteria easily comprehended to label an endeavor as pseudoscience when their adherents advocated that their claims or theories were scientific:

- The methods used to defend the beliefs are misapplied or misunderstood scientific methods.
- The belief itself is not capable of being scientifically tested.
- The belief is capable of being scientifically tested and has been falsified, but its adherents refuse to give up the belief (p. 193).

It is obvious that the difference between science and pseudoscience is mainly based on methodological issues. Pseudoscience is not a primer or primitive version of science. Since pseudoscientists use different methodologies and different testing procedures, pseudoscience and science differ in kind rather than in their degree. For those who have asserted that alternative treatment (for instance cupping therapy) works for them, it is not easy to scrutinize this treatment in a methodological manner. However, what makes something pseudoscience is not based on whether it works; rather, it is based on the methodology on which its proponents test their claims. Lilienfeld et al. (2012) clarified this situation by stating that "pseudoscientific practices are not necessarily entirely invalid or ineffective, but the assertions associated with these practices greatly outstrip the available scientific evidence." (p. 10).

It is obvious that there are differences between science and pseudoscience in their method of investigation and also in their approach to evidence. This is what makes the difference between science and pseudoscience in kind rather than in degree. However, it is also worth noting that "some fields begin as pseudoscience but gradually gain respectability by improving their standards and procedures" (Beyerstein 1995, p. 27). When it comes to a claim, it would be scientific or pseudoscientific; thus, what makes a claim pseudoscientific is the way that the proponents respond to this claim. According to Coker (2001), the aim of pseudoscience is to "rationalize strongly held beliefs, rather than to investigate or test alternative possibilities" (p. 1). As understood, pseudoscientists have a tendency to assert a claim and believe this claim to be true without making a meticulous investigation because they have experienced it as they claimed. Their understanding of methodology differs from that of scientists. Carroll (2014) confirmed this tendency by stating that "pseudoscientists claim to base their ideas on empirical evidence, and they may even use some scientific methods, though often their understanding of a controlled experiment is inadequate" (p. 1). Generally, having experience with something or having heard some testimonials about it is sufficient for pseudoscientists to test their claim. Additionally, Smith (2010) clarified the situation by expressing the importance of the methodology used in testing a claim. According to Smith (2010), as reported by the pseudoscientists, the result of this research may reveal a positive effect or may prove the effectiveness of a treatment until their methodologies are scrutinized. “When methodologies are improved, the effect disappears.” (Smith 2010, p. 282).

The Rationale of the Study

Research studies have consistently revealed that students and even science teachers have a naïve understanding of the nature of science (Abd-El-Khalick & Lederman 2000; Akerson & Donnelly 2010; Akerson et al. 2014; Aslan & Tasar 2013; Khishfe 2008; Lederman 1992; Lederman 2007; Moss et al. 2001) and of science itself (Metin & Leblebicioglu 2011; BouJaoude & Abd-El Khalick 1995; Carey et al. 1989; Kang et al. 2005; Sutherland & Dennick 2002). Additionally, it is also evident that pseudoscientific beliefs are widespread among the general population, students, and even among science educators (DeRobertis & Delaney 1993, 2000; Martin 1994; NSB 2002, 2012; Preece and Baxter 2000; Sugarman et al. 2011). There is well-documented evidence indicating that students in different age groups have various kinds of pseudoscientific beliefs such water dowsing (Happs 1991; Afonso & Gilbert 2010); astrology (DeRobertis & Delaney 2000; Happs 1991; Kallery 2001; NSB 2012; Preece & Baxter 2000); crystal power-healing gemstone (Preece & Baxter 2000); and ghosts, witchcraft, and telepathy (Lundström & Jakobsson 2009). For instance, in a most comprehensive and longitudinal study conducted by the National Science Foundation (NSF) since 1979, public understanding of Science and Technology is surveyed every 2 years by measuring the capacity of the public to distinguish science from pseudoscience. The survey mainly focuses on astrology as well as lucky numbers, unidentified flying objects, extrasensory perception, and magnetic therapy as pseudoscientific areas. Several reports have been published by NSF since the beginning of the study. According to one of the recent reports published in 2012, more than half of the young informants (54%) aged 18 to 24 are more likely to consider astrology to be very or sort of scientific (NSB 2012). In addition, belief in paranormal phenomena including psychic, extrasensory perception, extraterrestrial, and communication with the deceased increased in a 10-year period from 1990 to 2001 (NSB 2002).

In the following years, several researchers in the educational field conducted surveys to reveal belief-driven decisions concerning pseudoscience. The respondents of these surveys included students from high school (Nickell 1992), secondary and upper secondary school (Lundström & Jakobsson 2009; Preece & Baxter 2000), and university (DeRobertis & Delaney 1993, 2000; Johnson 2003; Sugarman et al. 2011; Walker et al. 2002) as well as pre-service teachers (Barnes et al. 2008; Losh & Nzekwe 2011) and in-service teachers (Kallery 2001). These studies consistently showed that pseudoscientific beliefs were widespread and were not related to scientific knowledge base or attitudes contrary to what had previously been assumed.

There are also studies focusing on the understanding of NOS in a pseudoscientific context. For example, Afonso and Gilbert (2010) investigated university students’ understanding of NOS using the water-dowsing issue in a pseudoscientific context. The researchers focused on the assumption that holding pseudoscientific beliefs might restrict the use of arguments based on NOS and constrain its understanding. They directed several questions to students to reveal their views on both working and scientific status of water dowsing, its efficacy, and their scientific research design for water dowsing. The results showed that many students believed in the working efficacy of water dowsing and provided pseudoscientific explanations based on personal experiences or resemblance reasoning. Furthermore, they were also unaware of the demarcation criteria between science and pseudoscience. On the other hand, the students who did not believe in the efficacy of water dowsing gave their reasons based on aspects of NOS.

Recently, Metin & Ertepinar (2016) investigated pre-service elementary science teachers' scientific and pseudoscientific beliefs about earthquake and explored their inferences about their understanding of science. The results revealed that some of the pre-service science teachers had pseudoscientific beliefs about earthquakes despite their science education background. The remainder of the participants could not present any scientific evidence concerning why they were in favor of a scientific explanation or why they did not believe in pseudoscience. In addition, the pre-service science teachers were not able to articulate the knowledge they acquired in the NOS course when asked to explain their pseudoscientific beliefs about earthquakes.

It is clear from the related literature that students are unable to demarcate science and pseudoscience (Martin 1994; Preece & Baxter 2000). However, there is no well-documented evidence concerning why students are unable to realize or identify the erroneous research design and flawed evidence on which pseudoscientific knowledge is based. In this respect, as stated by Carroll (2005), "it is not really the beliefs we should be interested in so much as the methods of arriving at and supporting those beliefs" (p. 193). Furthermore, Lundström (2007) recommended that "more studies where not only what types of pseudoscience students believe but also people's reasoning and argumentation in this subject should be of interest" (p. 5). Little is known about the reasoning of students about pseudoscience and how they articulate the aim, effectiveness, and scientific basis of pseudoscientific applications. Therefore, there is a need to identify the main reasoning patterns and underlying assumptions of learners in believing in the pseudoscientific enterprise to delve into their belief-driven decisions. Based on this, the present study aimed to uncover middle school students' understanding of the inherent aim of pseudoscientists and pseudoscientific applications related to crystals, and to reveal their judgments and justifications regarding the effectiveness and scientific basis of these applications. To this end, the following research questions were formulated:

1. What do middle school students think about the aim, effectiveness, and scientific basis of pseudoscientific applications, in particular crystal healing?
2. What reasons do they offer to support their ideas?

Methodology

Research Design

The present study was qualitative in nature. A basic interpretive qualitative approach (Merriam 1998) was used as the research design. The literature about pseudoscience is dominated by surveys on students' belief-driven decisions concerning pseudoscientific applications. However, researchers' recommendations (see Lundström 2007; Tsai et al. 2012) emphasize the necessity of studies investigating students' reasoning and argumentation in pseudoscience as well as their engagement in this subject to identify the factors underlying their belief-driven decisions. The best method to explore the students' attributions to pseudoscience is the qualitative method. Researchers who conduct a basic interpretive qualitative study "simply seek to discover and understand a phenomenon, a process, or the perspectives and worldviews of the people involved", and data are collected through interviews, observation, or document analysis (Merriam 1998, p. 11). The present study aimed to explore the meanings that the students assigned to pseudoscience: their knowledge and understanding of pseudoscience, what they considered to be the effectiveness and scientific basis of pseudoscientific applications, and the aspects of pseudoscience that made them consider it scientific and effective.

Participants

Participants of this research were 14 eighth graders (7 girls and 7 boys) who lived and went to school in rural areas. The related literature generally gave information about the beliefs of high school or university students about pseudoscience (Preece & Baxter 2000; Walker et al. 2002), but not that of middle school or younger students. Based on the suggestion in the literature that pseudoscientific beliefs begin almost from infancy (Whittle 2004) and younger students are engaged in pseudoscience (Tsai et al. 2012), it is reasonable to study middle school or younger students' reasoning in pseudoscience. However, there are some cognitive development stages such as sensorimotor, preoperational, concrete operational, and formal operational. In the formal operational stage, the adolescent or young adult begins to think abstractly and reason about hypothetical problems. This stage corresponds to the age of 12 and up and seventh–eighth grades and up in Turkish educational system. Compulsory education in Turkey consists of three parts including 12 grades. One to four grades are called primary school education, five to eight grades are called middle school education, and the last four grades are called high school education. At the end of the eighth grade, students are supposed to have basic skills and knowledge on science, mathematics, social studies, and literature. According to recent science curriculum published by Ministry of Education in Turkey (2013), the main goal of elementary science education is to develop science literacy. Those who are about to graduate from middle school are supposed to be science literate and also assumed to finish basic science education in Turkey. For this reason, it was reasonable to choose the eighth graders. Additionally, pseudoscientific beliefs and understandings are spread by the culture of the society. Considering the role of the family and other social environment on disposition to pseudoscience (Preece and Baxter 2000), the most important criterion supposed to have more influence on students' understanding was the district where students lived in. It was believed that applications such as cultivating according to "cemre" (a Turkish word referring to any of the three radiations of heat which supposedly fall in succession from the sun into the air, the water, and the earth in February and March), water dowsing, and healing with plants were much more common in village or rural areas. The study conducted by Tabata et al. (1994) showed that the use of medicinal plants rather than prescribed drugs is usually the first choice of treatment among rural people in Turkey and this finding would be evidence for this assumption. Sampson and Beyerstein (1996) indicated that because of traditional folk-healing in rural areas and modest education, people who live in rural areas are more likely to be prone to believing in pseudoscience, especially in health-related issues in China. Additionally, Rice (2003) found that rural residents were more likely to believe in the paranormal than urban dwellers in the USA. For this reason, it was found to be much more appropriate to interview students who lived and went to school in rural areas rather than the city center.

Pseudoscientific Context

The specific pseudoscientific context used in this study was crystal healing (Beyerstein 1995; Smith 2010), which is a type of alternative medicine practice. Researchers also use different terms for this practice such as crystal power (Moore 1992), crystal therapy (Baran et al. 2014), and crystal energy (Smith 2010). According to Lindeman (1998), we have a tendency to adopt alternative health care practices since they appeal to our experiential thinking with their characteristics of being emotionally laden, outcome-oriented, experience-directed, and self-evidently valid. Considering that pseudoscientific beliefs stem from experiential thinking, we chose one of the alternative health care practices as a pseudoscientific context. As Tsai et al. (2012) recommended, health-related pseudoscientific practices and practitioners should be the interest of research. Furthermore, evidence has shown that there could be differences between the genders concerning different pseudoscientific phenomena (Preece & Baxter 2000; Shermer 2003; Wiseman & Watt 2004). However, this difference was not apparent in the field of health (Lundström 2007). Thus, using a health issue as a pseudoscientific context was convenient for both females and males.

The other reason for selecting crystal healing was related to the degree of familiarity of the context. Furthermore, despite being known for its so-called effectiveness in the society, crystal healing is relatively less-debated in the media contrary to astrology and nonmedical remedies. Thus, it was assumed that students would be less exposed to negative or positive arguments about crystal healing, which would direct them to develop neutral or objective arguments.

In the present study, the pseudoscientific context was limited to crystal healing and therefore further research is necessary to investigate other contexts to provide an in-depth understanding of the middle school students' perceptions of pseudoscience. Due to the limited sample size and the specific demographic characteristics of the sample, the results of the study were interpreted cautiously and were not intended to be the basis of a generalization.

Data Collection

Data was collected through individual semi-structured interviews. The students were provided with pseudoscientific claims and pseudoscientific scenarios; then, they were questioned about the claims and scenarios and probed by further questions according to their responses. The researchers met with all the participants three times. Except for the first meeting, all interviews were conducted at a time and place convenient for the student. The duration of the interview ranged from 50 to 80 min. The interview protocol was organized into three parts: introduction, pseudoscientific claim, and ill-designed pseudoscientific research process. The introduction part aimed to reveal the students' understanding and previous knowledge about the subject that they had acquired during their life. A second aim of this part was for the students to become familiar with the interview subject and the interview process. The introduction part included questions probing the students' previous knowledge of pseudoscientific application. Students were asked what and how they knew about crystals, from what sources they had learned about crystals, what they knew about crystal healing, and whether they had encountered these types of applications before and if yes, how they had encountered them, what the aim of these applications could be, and why people use these applications.

The second part included pseudoscientific claims related to crystal healing. Some of the pseudoscientific claims used in this study were the following:

- Carnelian encourages positive thinking, is beneficial for insomnia (sleeping disorder), and regulates the blood pressure.
- Crystal quartz increases concentration, offers protection from negative energy, is beneficial for migraine, and is excellent for absorbing the radiation emitted by cell phones and computers.

These are actual pseudoscientific claims being spread across society and not hypothetical claims written for research purposes. The students were informed that these were just the claims stating the effect of the crystals on health of individuals which could be found in any visual or written communication environment. Then, the students were asked about their opinion on whether crystals could provide beneficial effects as they were claimed to do and to offer reasons to support their opinions. In addition, the students' ideas concerning how people constructed this type of knowledge and what research process and justifications they used were elicited. Finally, their perceptions of the scientific basis of the research processes used by pseudoscientists were examined.

The third part consisted of two scenarios (Balancing Blood Pressure and Growing a Plant) that were based on ill-designed pseudoscientific research process. The scenarios were developed by the researchers and reviewed by five experts who are experienced in science education. The students were expected to criticize the research designs stated in the scenarios. The aim of using these scenarios was to reveal the students' views about a flawed research process. These scenarios included unfair testing procedure. For instance, in the Balancing Blood Pressure scenario, the researcher neglected to incorporate control variables. The students were provided with the following text: "A researcher claims that carnelian can balance blood pressure. In order to test his/her claim, s/he decides to conduct a research with 15 individuals who are patients with high blood pressure. S/he provides a palm-sized piece of carnelian to each patient. Then, s/he asks them to hold the carnelian near to their heart. One hour later, s/he measures the blood pressure level." In order to give the appearance of being scientific, this scenario provided clues about the participants and setting. Additionally, it included terms of scientific process such as claiming, testing, and measuring something. However, it did not include any clue about the conclusion of the research.

The Growing a Plant scenario was built around a girl demonstrating the effect of crystal quartz on the growth of a plant. This scenario was used to determine the direct inferences of the students when they encountered the ill-designed research process presented in the scenario. We looked for evidence of the situation presented in the scenario by the pseudoscientist having an effect on students' ideas in terms of thinking positively about the effectiveness of crystal healing. The other aim of presenting this scenario was to explore the students' interpretations about the scientific process shown in the scenario. This scenario exemplified the remarkably unfair testing procedure used by pseudoscientists. The example stated in this scenario was related to the effectiveness of crystals on plants rather than human beings. Pseudoscientists generally use these kinds of examples to create counter-evidence in order to disprove the idea that the proponents of crystal power report specific sensations, positive physical effects, or feeling better because of the fact that they believe and are primed to feel in this way. Thus, the pseudoscientists demonstrate that plants have no ability to believe but are still affected by the power of crystals. The process in the scenario was also presented step by step giving an illusion of being scientific. The students were questioned on their interpretations about the process used in these scenarios with the main point being whether they had realized the flawed research process. Finally, their judgments and justifications regarding the scientific basis of the research processes used in these scenarios were examined.

Data Analysis

The data collected in present study were analyzed using the constant comparative method (Glaser and Strauss 1967). In this method, data analysis is conducted in the three essential of open coding, axial coding, and selective coding (Glaser & Strauss 1967; Johnson & Christensen 2012; Strauss & Corbin 1990). In the first stage, raw thoughts of the participants were converted into codes. In the axial coding stage, the codes were organized and recategorized according to their similarities. In the last stage, the emerging themes were connected with a central idea by organizing them to constitute a storyline that had a potential to answer the research questions (Creswell 2006; Strauss & Corbin 1990). Table 1 represents the exemplary coding structure. For instance, in the open coding, the quotations of the students were coded into sub-categories such as boosting energy, relieving stress, birthstone, and luck. Then, these sub-categories were organized according to their common ground. In this case, the common ground of these sub-categories is being superstitious. In the last stage, the themes such as superstitious, medical, helping people, and making profit were connected with each other around the central idea of "views about the aim of pseudoscientific applications."

In the coding process, the first researcher coded the data and the other researchers that were expert in science education and experienced in qualitative research checked the coded data and resolved the discrepancies by discussing it and reaching a consensus. This peer-review process provided a more powerful analysis and increased the reliability of the study. In addition, the first researcher determined the intra-coder reliability by randomly selecting two datasets. She coded these datasets twice at an interval of 12 days. The intra-coder agreement was found to be .91 demonstrating a high level of agreement (Johnson and Christensen 2012; Miles et al. 2014).

Table 1 Exemplary coding structure

Core concept	Major theme	Sub-categories	Exemplary quotation
The students' views about the aim of pseudoscientific applications related to using crystal	Superstitious purposes	Used for boosting energy	I believe that crystals give positive energy and make me relax as herbs do.
		Used for relieving stress	There are colorful crystals. There is a particular crystal for each emotion. For example, stress gemstone can relieve stress.
		Used as a birthstone	Birthstones come to mind. A different birthstone representing each month. I like them.
		Used for luck	It is told that colorful gemstones bring good luck. Each gemstone serves a different purpose.

Results

Inherent Aim of Pseudoscientists and Pseudoscientific Applications

This section analyzes the students' views about the aim of pseudoscientists and pseudoscientific applications. The results revealed that most of the students were not aware of the essential aims of pseudoscience. Regarding the aim of pseudoscientific applications related to using crystals, the students' ideas were categorized into four themes: medical purposes, helping people, superstition, and making profit. The results revealed that most students ($n = 11$) believed such practices were adopted for medical purposes. They stated that due to the various therapeutic characteristics of crystals, each crystal was used to cure a different disease. Below is an excerpt from the students' responses to demonstrate their familiarity with crystals and their views about using crystals for medical purposes:

> S: My mother uses natural crystals or similar materials a lot. Moreover, people say that crystals bought from the Hajj are also curative and my mother always keeps them. Generally, people use them to cure something. They use crystals and so forth for backache. I have heard about them and seen them.
> R: Where did you see them?
> S: My mother has a CD, she believes in things like cupping. She also has a ring to relieve stress. A ring made of onyx. She uses it.
> R: Has your mother told you whether that ring has been good for her?
> S: She has not told me whether the ring has been good for her but she often uses it. She thinks that perhaps the ring will be good for her someday. However, she has said that crystals are good for back pain or at least she has heard that they are good for backaches.
> R: Do you have any other observation about this topic?
> S: No, but I heard something about coral crystals. My grandmother uses them. She has a cutaneous disease. She uses wristbands made of coral crystals to cure her disease. (Zehra)

Some of the students ($n = 3$) also mentioned the existence of spas and cure or treatment centers, in which crystals were used for medical purposes. Two students also reported to have seen or been to such a treatment center that aimed to cure herniated disc disease and rheumatism using crystals. Three students saw a spa brochure showing black round-shape crystals on the back of body. The students' experiences indicated how pseudoscientists interested in crystal healing convinced people to purchase and use crystals by applying a tactic based on so-called first-hand experience or hearsay reporting the effectiveness of crystals. The following excerpt demonstrates the students' experience related to such treatment centers:

> S: This summer, a health center on crystals was opened here. There was a machine there and a mobile crystal under that machine that was good for backaches. In fact, I did not have a backache but I accompanied one of my friends. They put hot crystals on people's backs there. I remember that.
> R: What are the reasons directing people to these treatments?
> S: I do not know but they seem convincing. When you see a doctor, he writes a prescription or he operates on you but here [in these centers] crystals treat people. Being treated by crystals is easier for people because they are given information about crystals

in these centers. Then, the owners of these places give examples; such as how a person went there, used the crystal, lied on the bed and recovered. Some people in these centers also say that one of their close relatives used it and recovered quickly. Once you hear something like this, it is more believable. (Ceren)

In helping people theme, nine students thought that people interested in crystals and crystal healing used these materials to help people suffering from particular diseases. Six of them stated that the aim of the pseudoscientists was to promote the crystals and their usage on health in order to help people. However, these six students were not aware of implied commercial aim that lies behind promotion of crystals. This is evident in the following excerpt from the interview:

S: They promote crystals. In the street fair, there are brochures about crystals.
I: What is written on these brochures?
S: Properties of crystals. That is to say, this crystal is good for particular disease and it relieves you in that way. The more they promote, the more people use them, the more people are treated by these crystals. (Esra)

As understood from her quotation, she focused on informing papers about crystals provided there instead of commerce. She gullibly thought that salesmen of crystals just try to make other people informed about crystals so that more people could be able to use them. In parallel, other students indicated that people interested in crystals and asserted positive claims about crystals just want to give advices to other people. For instance, given quotation below was related to this:

S: I think they want to help people. They share their knowledge about these crystals. In other words, they want other people to know and use them. They say that people who do not rely on doctors for medical advice and treatment can also use these crystals. They just give advice based on their past experiences of crystals to people who are similar to them. (Fatih)

Some other students ($n = 6$) stated that crystals were used due to superstitions. In this theme, four students stated that they had heard about or seen cases, in which crystals were used to increase an individual's energy and positively affect their mood. Another superstitious purpose of using crystals as stated by the students was to relieve or reduce stress. Four students mentioned that their mothers or elder sisters often used crystals to get rid of their stress and relax. There were also students ($n = 3$) who reported that crystals were used as a birthstone representing each month or a luck stone to bringing good luck holder. The quotation below exemplifies one girl's experience with her mother using the crystals for superstitious purpose:

S: My mother buys these crystals wherever we go. According to my mother, crystals relax her and receive negative energy. Some of them may be good for diseases. Some of them are harmful. There are also books about them showing horoscope sign. My sign is bull. My mother has bought it to me. She searched on the internet afterwards. (Esra)

Five students approached the issue more skeptically and considered that the aim of using crystals was to make profit out of people who were inclined to hold pseudoscientific beliefs. In this theme, one student explained his views as follows:

S: I think it is commercial. I do not know whether crystals cure diseases but people interested in crystals have commercial aims. They just want to earn money by exploiting

> people's weaknesses. They set up websites for this reason. They give information about crystals. They mention that crystals are good for and cure certain diseases. When people believe in it, they want to try it themselves. People think that it may cure their diseases. They try it as they cherish a hope. (Cem)

In his quotation, he advocated that the initial aim of people interested in crystals was to earn money by promoting crystals on their websites and he claimed that promoters of the crystals also abused patients' hope of recovery in order to make money.

Effectiveness of Pseudoscientific Applications

Most of the students made experience-directed and self-evidently valid decisions in judging the effectiveness of crystal healing. Fifty percent of the students considered such practices as effective in treating diseases. The reasons given by the students were related to their personal experiences and the effect of social environment, media, and verbal persuasion from their families. The themes that emerged related to accepting efficacy were media priming effect, positive assumption, and social impact. In media priming effect theme, the students mentioned hearing about the efficacy of these practices from media, especially TV programs broadcasted midday. The students found the so-called effectiveness of the crystals convincing since these programs informed them about crystals and their positive impact on health. This is evident in the following excerpt from the interview:

> S: I think crystals are definitely effective. I think these crystals may have these effects. I have already heard that amethyst is effective in treating skin diseases. I heard this on a TV program. I have also heard something about quartz crystal. Hearing about the effectiveness of these two crystals on TV programs made me have a more positive attitude towards them. I am also reading things about them. They must be effective since there are not only TV programs but also books about them. I think this information is correct. (Furkan)

Some of the reasons were based on the participants' positive assumptions about crystal healing. For the students coded in positive assumption theme, crystal healing was regularly employed by many people in their social environment for health purposes and most of them continued to use these crystals that this meant that these crystals must be effective as presented. This view was presented by one student as follows:

> S: It is effective in any case.
> I: Why do you think that it is effective?
> S: Let me talk about that center [for crystal healing] again. For instance, there were a lot of people inside the center at the opening and a lot of people inside on the following days. Besides, I have also seen the same people. In other words, people have been there repeatedly. That many people have been there and some people have been there repeatedly made me think that it has been effective. I suppose that if it were not effective, people would not go there. (Ahmet)

The students coded in positive assumption theme reasoned that crystals must be effective; otherwise, they would not be used by so many people, the claims about them would not have emerged, or there would not be so many claims about crystals.

The other theme is social impact including verbal persuasion and personal witness. Related to verbal persuasion, the students indicated that hearing the same information about the crystals from different sources was one of the most important factors that made them believe in the efficacy of these crystals. According to these students, when the information about crystals or crystal healing came from different sources such as relatives, friends, elder people, and the media it increased the reliability of these claims for them and made them believe. A representative excerpt of the importance of hearing from different sources from one student is given below:

S: This information seems persuasive and reliable to many people. I think if it is available everywhere, it becomes more persuasive and reliable. I would trust it more if I saw and heard about it everywhere. (Deniz)

The other reason that the students gave was having positive eyewitness testimony and the excerpt from an interview reveals their thoughts concerning the reliability of the claims about crystal healing:

S: I do not like making a comment about anything before trying it. However, I think this can happen (effectiveness of the crystals). My grandmother told me something about herbs before. She has used them and I have witnessed that these herbs have worked for her. For this reason, I believe that the crystals may also have the same positive effect. This is really reliable information for me. (Onur)

On the other hand, only three students were skeptic about the effectiveness of crystal healing. These students further explained that such a small stone could not possibly have an impact asserted in claims. They believed that these crystals could not treat any diseases. In addition, these students indicated that people with an illness should use prescribed drugs for treatment. Only one student stated that he did not believe in claims about the effectiveness of crystal healing due to the lack of scientific evidence or explanation as shown in the following excerpt;

S: To tell you the truth, this kind of information does not sound logical to me. It is just a stone. How can a stone have this much effect? It is non-sense. How can an ordinary stone cure a disease? How can a stone cure a disease inside me?
R: However, there are people claiming that these crystals have these kinds of effects.
S: I think a man gets ill. He uses the crystal. After a while, he gets better. Then, he begins to think that it was the crystal that was good for him. Perhaps he was going to feel better in time anyway. This is not logical for me. I mean, I think his health would get better but by chance he starts using the crystal at the same time. Therefore, he begins thinking that he has got better thanks to the crystal. Actually, getting better is not at all related to the crystal. If crystal was effective on health, there would be a scientific explanation. These things do not seem scientific. (Kemal)

In his interview, Kemal made a rational explanation about why some people assumed that crystals would cure them. His explanation was based on the existence of two separate facts that were associated by an individual. Specifically, he emphasized that there would be a scientific explanation demonstrating the effectiveness of crystals if they really worked.

The remaining four students were not sure whether crystals were really effective on health. However, despite being hesitant to make a decision about the effectiveness of crystal healing, they seemed to be closer to accepting it.

Scientific Basis of Pseudoscientific Applications

This section analyzes the students' opinions about the scientific basis of crystal healing and their reasons. This data was obtained using the Growing a Plant and Balancing Blood Pressure scenarios, and pseudoscientific claims.

In terms of pseudoscientific claims, most of the students ($n = 11$) classified the crystal healing claims presented in this study as scientific knowledge for several reasons. Eight students believed that these were no longer claims since they had been tested on human beings. The students justified these claims by stating that they must have been researched scientifically before being proposed; otherwise, there would not be so much information about them. The reasoning of the students was based on the assumption that if there were such assertive claims about crystals and their impact on health, the claimers must have tried them on many people before they published these claims. This was evident in the following excerpt from an interview:

> S: People have said these things; that is to say, there is something like that. It has been tested and observed. I think they are scientific. If they were not scientific, why would people write things about them? Therefore, a coral crystal is something people have mentioned. Since it has been mentioned that it increases the level of concentration, this must have been tested before. In other words, it must have been tested on millions of people, not only a few people to find this result. I think I trust them. (Fatma)

Four of these students also stated that the effectiveness of the crystals had been proven by experience. The following excerpt is from one of these respondents;

> S: My grandmother has different diseases such as high blood pressure and diabetes. She also has back pain. She asked me to fetch a crystal she had bought before. I took the crystal to her and she put it on her back. Then, she told me that her pain had gone. I would obviously share my experience about something like this on the internet if I were a manager of a website. I think it is scientific. You have unproven information and in order to prove it, you try it yourself. These trails would provide the evidence for it. By testing them on human beings, you also test its effectiveness. Therefore, these trials are scientific. (Baran)

In addition, seven students stated that these claims were scientific since such practices produced effective results as shown in the following dialog:

> S: It is already scientific; I naturally think that it is scientific because they have researched it and found positive results. If people believe that it has cured them, it is scientific. And if it really cures people, it really has a positive effect. In other words, if it did not cure diseases, why would people say that this crystal is good for this disease and that crystal is good for that disease? I mean a man or a woman gets ill and then he or she gets better; this means that particular crystal cures that particular disease. In other words, you get a result. You get information and you get a result. Therefore, it is scientific. There are a lot of reports of the effectiveness of crystals and positive results. (Cem)

Only three other students found the claims regarding crystals not to be scientific. One student stated that crystal healing was not a subject that could be scientifically investigated because it was impossible to directly measure the effect of crystals on health. Another student reported that she would only believe absolutely proven facts which had been scientifically investigated. The third student stated that such claims were not based on any scientific evidence and there was no scientific explanation showing the effectiveness of crystals. Thus, he did not consider these claims to be scientific as given in his response below:

> S: Well, I do not think that these claims are correct. I mean, there must be a scientific explanation. These things do not seem to be scientific. Frankly speaking, I have not heard any scientific explanations about them so far. Sometimes people recover from diseases after using crystals but this is just a coincidence. (Kemal)

The results on the students' opinions about the scientific basis of the research process presented in the Growing a Plant scenario were similar to the data presented above. Ten students classified this process as a scientific experiment. Eight reported that the effect of crystal was tested by the girl that grew a plant using a crystal in the scenario. These students believed it to be real because it was tried by someone in an experiment. Below is the transcript of the response of a participant:

> S: She tested quartz crystal on a plant. She took notes about the changes in the plant. She observed that the plant turned towards quartz crystal and began to grow. This is an experiment. The crystal was really tested by the girl. The girl did an experiment in her house. For instance, her testing the quartz crystal and taking notes are part of an experiment. It is true. (Semih)

One student considered that going through a process step by step as in science would make the result scientific. Therefore, she believed that the process presented in the scenario was a scientific experiment. Interestingly, six students focused on the positive results as being the indicator of the scientific nature of a process. These students thought that all scientific experiments must have a positive result:

> S: Girl's trial showed the plant's tropism in that the crystal instead of the sun gave the energy, and the observations showed that the plant turned to the crystal instead of the sun. These observations are part of a scientific experiment. In order for the event to be scientific, the plant turning to the crystal, growing, becoming thicker, developing and blossoming in this experiment are all necessary. For example, if someone puts a crystal near a plant but the plant does not grow and even dies; then, this is not something scientific. I think this application is scientific because this experiment was successful. It is the quartz crystal rather than the sun that makes the plant grow. (Cem)

Four students were more skeptical than the others and stated that the process presented in the scenario did not represent a scientific experiment. However, except one, all the reasons they proposed were very superficial and did not point out the errors in the research design presented in the scenario. For instance, one of them considered that in order to refer to something as scientific, it should be conducted in a laboratory. Interestingly, only one student realized that the girl in the scenario did not control any variable and therefore the result might have been biased; thus, he did not consider this process to be a scientific experiment:

> S: Just watching something on a TV program is not enough. Since she did not research its validity and prove that, her testing was wrong. She had to first research it in detail. Let's assume that you want to be taller and you have tried several ways to achieve that and you have found the right way but this way may lead you to a mistake since you have

not conducted detailed research beforehand. This is a really bad situation. I think it is not scientific for this reason. She should have researched how to use it before [testing it]. She began testing it right away without researching anything. Therefore, it [the process] cannot be considered scientific. She should have explored previous research; whether there was any scientific information about it. In other words, she should have referred to the reports of experts in the field. She should have read their comments. This way, she could differentiate between the right and wrong. Thus, she could learn what she should do. (Baran)

Regarding the students' opinions about the scientific basis of the process presented in the Balancing Blood Pressure scenario, most of the students ($n = 11$) reported that the research process followed by the researcher in the scenario represented a scientific investigation; therefore, it was very scientific. Similarly, six students referred to the getting of results as an indicator of being scientific. In addition, studying with a sufficient number of participants and undertaking measurements and experiments were among other reasons offered by the students that accepted this process as scientific. The transcript of a student's view of undertaking measurements as an indication of the process being scientific is given below:

S: He tested it on 15 people. He did that as in the example I had given about my grandmother. He tested it both before and after the experiment as I mentioned. If I were him, I would do research like that. I think this is scientific research because he worked with 15 people; therefore, it could not have happened by chance. It is good to take measurements before and after the experiment. This way, he can compare the two measurements. He measured the blood pressure of 15 people. This kind of research clearly shows whether crystal works. (Kemal)

Two students thought that the researcher in the scenario asserted a claim about the effectiveness of crystal on high blood pressure, and then he tested this claim by conducting research; therefore, his attempts were scientific:

S: I think this is scientific research. I see a person testing the effect of a crystal on 15 people. If I said that I would get 15 people and do the same, this would not be considered scientific research. However, there is a researcher here who has a claim based on his previous research.
R: Why do you think that it can be considered as scientific research?
S: He must prove that it is something good. He is doing research for this reason. He has not produced and presented it yet. He tests it before presenting the product to see whether it is useful for people. If I do this to support people, this research becomes more scientific for me. If I only know this and give it to people, it is not scientific research because I already know the effect of it. However, proving something from scratch is science. (Merve)

The remaining two students were hesitant about the scientific basis of the process presented in the scenario. Only one student approached skeptically to this process by stating that the results might have been affected by many other reasons apart from the effect of crystal. For this reason, he explained that this process was not a scientific investigation as follows:

S: I do not think every research is scientific because the only thing people feel when they place the crystal on their heart is tiredness. They attempt to take the crystal away. I think it will not work because of this reason. It is not very scientific because people will have certain thoughts, which will affect the result of the research. First, this person must continue his daily life. Let's assume that you are using onyx. If you behave in a different way on purpose knowing that onyx is near you, this is not very scientific. On the other hand, you may believe that it is effective since you are psychologically affected by this crystal. For instance, let's say your mother has a high blood pressure and you put onyx in several places in the house. Your mother does not know this; therefore, if her blood pressure does not increase for a week when it generally increased once or twice in a week before, then we can say that this crystal really works. (Baran)

Discussion

Although we have many criteria in order to differentiate science from pseudoscience, when it comes to applying these criteria to daily practices, we face certain challenges since gaining knowledge is very different from having the skills to put the knowledge into practice. In order to distinguish between science and pseudoscience, people need to understand the essential aims of pseudoscience and pseudoscientists, their knowledge construction processes and reasons underlying their tendencies. Coker (2001) stated that the essential aim of pseudoscience was "to rationalize strongly held beliefs, rather than to investigate or test alternative possibilities" (p. 1). According to him, pseudoscience is interested in favorable conclusions which address preconceived ideas and widespread misunderstandings. As explained previously, these preconceived ideas and widespread misunderstandings are generally based on reasoning errors such as confirmation bias. According to Good (2012), "people marketing a particular pseudoscience often take advantage of one or more of these biases to convince people to believe in the effectiveness or 'truth' of their product and the placebo effect does the rest" (p. 103). Beyerstein (1995) explained the commercial interest in pseudoscience giving examples of pseudoscientific practices such as spiritual healing, quack cancer cures, and crystal healing. Beyerstein (1995) also stated, "pseudosciences invite us to buy into the desirable but unobtainable dream of abundance, health, and happiness for all" (p. 32). Today, painless and effortless treatments are advertised in the market including crystal healing, in which bracelets and rings made of crystals are used and sold to people looking for hope. Therefore, one of the essential aims of pseudoscience can be summarized as making money by capitalizing people's hope, despairs, reasoning errors, and their disability to distinguish science from pseudoscience. The commercial stake in pseudoscientific claims was also pointed out by other researchers such as Bunge (2011), Coker (2001), Moore (1992), and Preece and Baxter (2000).

The results of this study revealed that the students were not aware of the essential aims of pseudoscience. Especially in the context of crystal healing, they did not realize that there were commercial interests in these types of treatments. The students generally believed that crystals were mainly used for medical purposes. The students revealed their gullibility in stating that they would promote the use of crystals to help other people suffering from particular diseases by offering advice about using crystals or healing them with crystals. Interestingly, some of the students stated that their relatives or they used crystals due to their superstitions believing that they would boost their energy, bring them luck, and relieve their stress. On the other hand, a few students were aware of the deception involved in such practices. These students stated that the initial aim of using crystals was to make profit by selling crystals to patients who were looking for hope, and by deceiving people through the promotion of ineffective objects. Based on these results, it can be concluded that most of the students did not have an understanding of the inherent aim of pseudoscience, which is based on deception and commercial gain. In their study on the attribution theory, Robertson and Rossiter (1974) found that children that realized the persuasive intent of commercials tended not to trust commercials while those that considered that commercials had an assistive intent believed them more and attributed them a positive meaning. Accordingly, in the present study, the students' gullibility was as a result of their attributions about crystal healing. Most students attributed a positive meaning to crystals believing that they would cure, help, and guide people; thus, they tended to perceive the assistive intent of crystals and crystal healing, not recognizing their persuasive or deceptive nature of such practices.

The students generally made pragmatic inferences about the goal of pseudoscientific applications related to crystals and crystal healing. Their reasoning about the aim of using crystals and crystal healing was fundamentally based on their pragmatic interpretations such as having been cured, having been helped, and having been advised. For this reason, it could be claimed that the students in the present study were so gullible about the aim of using crystals and crystal healing that they were very prone to pseudoscientific applications in that area.

Regarding their opinions about the effectiveness of crystal healing, except three students, all the participants had a viewpoint close to that of the pseudoscientists. They either already accepted the so-called effectiveness of crystal healing or they seemed to be close to accepting it. Their reasons were mostly based on personal experiences, in which they witnessed one of their relatives benefitting from crystals. Other reasons included hearing about similar cases from the media, especially TV programs. The students found the so-called effectiveness of crystals convincing since there were TV programs providing information about crystals and their positive impact on health. In addition, of the three students that was skeptical about the effectiveness of crystal healing, only one stated that there was no scientific evidence and explanation to support such claims. The other students were hesitant about the issue. Most of the students did not consider the process of collecting data, accumulating evidence, or providing an alternative explanation. As pseudoscientists do, these students overlooked the essential principles of a scientific investigation. In addition, except one student, none of the participants critically evaluated the pseudoscientific claims and the research process that was necessary to evaluate the effectiveness of crystals. They mostly believed that the claims were genuine and they were based on personal experience and trial and error processes. In light of these results, it can be concluded that the students mostly had less sophisticated scientific epistemology, which was contrary to the idea that "knowledge comes from reasoning, thinking, and experimentation" (Elder 2002). Similar results were reported in other studies. For instance, Driver et al. (1996) explored the epistemology of students aged 9, 12, and 16 years and identified three types of reasoning, namely, phenomenon-based, relation-based, and model-based. Most of the students were classified into the phenomenon-based reasoning group, in which the students only focused on a particular phenomenon and described it rather than considering all the variables to draw empirical generalizations and evaluating explanations in light of evidence.

Additionally, the students' tendency to believe in efficacy of crystal healing could be explained by pragmatic and post hoc fallacy. Pragmatic fallacy is the act of approving something is true because of its perceived benefit that is supposed to be provided by it. Likewise, pragmatic fallacy is commitment to a belief that assertion must be true, just because it seems to work (Smith 2010). It derives from our perception of something as satisfying, convincing, beneficial, making you feel better, and working on you as you suppose. When we observe these satisfying outcomes, we tend to think of that it must be true in accordance with pragmatic fallacy. In this case, the observer is just interested in fulfilling his/her outcome expectation without criticizing truthfulness of the assertion. Briefly, as Carroll (2014) indicated that an individual considers practical benefit or utility in believing that something is true without considering whatever its truth value is. For instance, you made an argument that when I wear evil-eye jewelry, I feel better and protected; therefore, it must be more of a true belief than a superstition and it also must be true that the evil-eye jewelry protects us from others' jealousies. It is a typical kind of pragmatic fallacy. In this case, you have a tendency to believe in working the efficacy of evil-eye just because wearing it makes you feel better and makes you believe that it works on you.

The post hoc fallacy is derived from the Latin phrase "post hoc, ergo propter hoc" which means that "after this, therefore because of this." It is a tendency to see two facts occurring in a sequence related in a causal way. For instance, Coker (2001) gave an excellent example in order to differentiate the two different perspectives of science and pseudoscience. His example is that "Joe Blow puts jello on his head and his headache goes away" (p. 1). According to scientific perspective, it does not mean anything due to the absence of evidence. However, from pseudoscientific perspective or post hoc fallacy perspective, it means that jello cures headache, even it could be used as an anecdotal evidence to prove jello's efficacy. In fact, it does not mean that two facts following each other in a sequence are connected in a causal way. Similarly, Smith (2010) clarified that occurring at the same time does not mean that one fact caused the other fact. There are four possible reasons that might explain the co-occurrence of two facts. However, people who have post hoc fallacy tend to selectively choose just one of these reasons that seems both simplistic and satisfying. As understood from the example, people preferred to see what they expect to see among the four equally possible facts. Furthermore, for most of the people seeing something on their own would be more convincing than others would. It could be called "seeing is believing tendency" of our brain and in this case, it could explain why the students considered verbal persuasion, eyewitness testimony, and other social impact. In nature of science literature, it is called "seeing is knowing" (Khishfe 2008; Khishfe and Lederman 2006) and indicating misconception about how science is done. In fact, it refers to the process in which only concrete or visual evidence is convincing. In this process, if people see something with their own eyes, they tend to believe that it is true, it exists, and it is more convincing.

In terms of their views concerning the scientific basis of crystal healing, more than half of the students considered that pseudoscientific claims and processes presented in the scenarios were scientific. Their argument was derived from their understanding about scientific inquiry. According to the students, in order to test something scientifically, it was sufficient to try it on a human being in a real situation. In addition, the students believed that in order to refer to a process as scientific, there had to be a positive result as the final product of the process. For instance, most of the students thought that pseudoscientific claims and processes by which these claims were constructed were scientific because people using crystals tested their claims by trying the crystals themselves or on other people and obtained positive results showing the effectiveness of these objects. In a similar manner, they thought that the pseudoscientific practice adopted in the Growing a Plant scenario was a scientific experiment since the girl used crystal quartz on a plant (trial) and observed that her plant grew (positive result). Similarly, regarding the research process presented in the Balancing Blood Pressure scenario, most of the students considered it to be scientific. Similar to the first scenario, the students focused on getting a positive result after experimenting with crystals and comparing the blood pressure measurements before and after the experiment. There were also distractors used in the scenario that made the students think that the pseudoscientific process was scientific. For instance, existence of observations and measurements, referral to the number of participants, arranging processes in an order, and the experiment being conducted by experts gave this process the illusion of being scientific. According to Good (2012), "one way to assert authority is to invoke science to support claims, and getting people to believe a claim is easier if science, or what seems to be science, is used to support the claim" (p. 98). The selective use of science, using a technical language, and giving it the illusion of being scientific are among the techniques used by pseudoscientists. In some cases, it is very difficult to distinguish scientific terms from pseudoscientific terms. Ladyman (2013) provided an example for this by referring to a speaker using the pseudoscientific term of "proton torpedoes." In this case, the speaker would consider herself to have a sensible scientific theory and her audience would suppose that her claims were scientific and true. The misleading use of technical language was also addressed in the study by Weisberg et al. (2008), who found that irrelevant information given in a more technical language made university students unable to distinguish plausible and implausible explanations. This was also the case in the present study, in which almost all the students were not able to make such a differentiation. A similar result was reported by Kallery (2001), who reported that there was consistent evidence presented for the scientific basis of astrology. Kallery (2001) found that the majority of the teachers (59%) viewed both astronomy and astrology as scientific, and they could not distinguish between science and pseudoscience. Similarly, according to a study by NSB (2012), more than half of the youngest informants (54%) were more likely to accept astrology as sort of scientific. Furthermore, in the study by Turgut (2011), the majority of the pre-service teachers hesitated to refer to astrology as pseudoscientific; however, none labeled it as scientific. An important and interesting result was reported by Afonso and Gilbert (2010), who investigated the students' views on the effectiveness and scientific basis of water dowsing as a pseudoscientific context. The authors found that most of the students believed in the effectiveness of water dowsing and classified it as traditional, not scientific knowledge.

According to the results, the vast majority of the students did not attempt to evaluate the scientific basis of pseudoscientific claims and applications related to crystals and crystal healing based on the availability of data and evidence obtained through experimentation or testing. They just paid attention to the information presented in scenarios that seemed to indicate that the process was actually real and the experiment was performed by real people. Therefore, the students thought that since the effectiveness of crystals was tested by real people, the results were no longer a rumor making the process scientific. Therefore, it can be concluded that the students were not able to distinguish scientific and pseudoscientific practices.

Conclusion

According to the results of the study, it can be concluded that the students were very gullible about the aim, effectiveness, and scientific basis of pseudoscientific practices and in particular the use of crystals. Furthermore, similar to pseudoscientists, the students generally used weak reasoning to evaluate the presented claims and research designs about crystals and crystal healing.

The students attributed a positive meaning to the purposes of pseudoscience. A vast majority of the participants were not aware of the concealed commercial and deceptive interests of pseudoscientists. When discussing the effectiveness of crystal healing, most of the students did not consider the process of collecting data, accumulating evidence, or providing an alternative explanation. In terms of the scientific basis of these claims, they did not focus on scientific indicators such data, evidence, and justification. In parallel with pseudoscientists' way of thinking, the students believed that if an idea was tested by someone or on someone and the result was positive, this was sufficient to support that the claim was scientific.

In brief, the students were found to have very gullible viewpoints about pseudoscientific claims and research design. These results are important in terms of demonstrating the necessity of not only science education but also raising responsible citizens. Citizens who have a tendency to accept pseudoscientific applications without question, believe what they are told without reasoning, use personal ideas, intuition, anecdotal, or testimonial evidence to make decisions, and have the tendency to rely on personal trial and error processes instead of applying basic science process skills would have difficulties in actively participating in decision-making processes in many aspects of their lives. However, as science educators, we demand responsible citizenship, in which the individual takes part in the decision-making and policy-making process about scientific issues, who critically evaluates what is presented as scientific or pseudoscientific and uses rational thinking in order not to be deceived by practices which fall outside the realm of science.

According to result of the present study, the students are so vulnerable to social culture in terms of pseudoscientific beliefs. Most of their opinions, assumptions, attributions, and judgments are influence by the society surround them. Consequently, social reinforcement and importance of group thinking would be asserted as main reasons of pseudoscientific beliefs (Carroll 2005; Eve & Dunn 1990; Janis 1972; Nisbet 2006; Preece & Baxter 2000). Specifically, Carroll (2005) made an analogy of pseudoscience with viruses and clarified that as a result of communal reinforcement, the pseudoscientific beliefs are delivered and maintained their existence. Additionally, Janis (1972) emphasized how group thinking influences and weakens our reasoning skills when we encounter pseudoscientific application; if the group agrees with a decision, individuals in the group tend to obey the decision of the group and do not need to criticize or evaluate the decision. Accordingly, as Carroll (2005) underlined that "It is always easier to believe something, no matter how wild or weird, if others believe it, too" (p. 212).

The study focused on uncovering the students' perspective concerning their gullibility, vulnerability, and abusability to pseudoscience and their tendencies towards using pseudoscientific reasoning. The students generally used weak reasoning that was similar to that of pseudoscientists when assessing pseudoscientific claims. For instance, they used their personal feelings, testimony, and anecdotal information, and were influenced by media priming effect and social influence around them when forming opinion about pseudoscientific applications instead of using rational thinking. However, "the habit of forming a judgment, unbiased by personal feeling, is characteristic of what may be termed the scientific frame of mind" (Pearson 1900, p. 6). In terms of scientific literacy, students' tendency and their gullibility, vulnerability, and abusability to pseudoscience are not an appropriate frame of mind. The basic science education in the middle school curriculum needs to be reorganized in accordance with science literacy, aiming to train those who would be able to "judge claims based on lack of empirical evidence, testimonial or anecdotal evidence, unfalsifiable theories or simple correlational data as weak claims" (Lawson 1999, p. 207). Science education not only has a role in individual level but it is a driving force behind future development in terms of society. This study provided evidence that mass media and relatives have a huge effect on students' opinions about pseudoscientific applications. Most of the time, these second-hand sources provide more accessible and acceptable information about these applications for students. For this reason, it is reasonable to agree with what Roth and Lee (2002) proposed; "scientific literacy as a property of collective activity rather than individual minds" (p. 33). In this manner, science literacy should be considered as a social goal including specific everyday situations such as making decisions about socio-scientific issues, finding sustainable energy sources, or choosing the best farming practice as well as scientific topics and skills. Pseudoscience, quackery, occult, and superstition are equally important problems for society that need to be handled in terms of science literacy. In this manner, education should prepare people to critically assess different kinds of assertions and claims, to search for evidence and to differentiate strong arguments from [pseudoscientific] arguments (AAAS 1989). Otherwise, as Beyerstein (1995) stated, "the climate in which pseudosciences thrive contributes to a decline in science literacy and critical thinking" (p. 42).

In future work, the students' perceptions of pseudoscience can be investigated by comparing their understanding of science and pseudoscience. Such research can be designed in a way that will help explore students' approaches to inquiry in both scientific and pseudoscientific contexts. This will allow the researchers to identify the similarities in both contexts, which would also provide an insight into why the students consider pseudoscience as scientific. Additionally, further research should be conducted in order to understand why students from various backgrounds hold different pseudoscientific beliefs. This could be achieved by delving into the students' belief systems about pseudoscience and uncovering the features that orient their belief-driven decisions in pseudoscientific applications.

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