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Turkish adaptation of the science-P reasoning inventory: examining the relationships between epistemological beliefs, gender, and residential area

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ABSTRACT

Background: In recent years, studies on scientific reasoning have shown that primary school students can demonstrate scientific reasoning in various tasks. Many studies conducted in Western countries have developed instruments to assess such reasoning skills.

Purpose: This study examined the psychometric properties of the shortened Turkish version of the Science-P Reasoning Inventory (SPR-I). Then, it investigated the relationship between SPR-I and gender, as well as epistemological and residential areas. In this context, the study was structured as Study-1, which tested the validity and reliability of SPR-I, and Study-2, which investigated the relationship between SPR-I and variables.

Sample: A total of 425 students aged 9–13 years in Turkey participated in the study. Data was collected in the 2023–2024 academic year.

Design and Methods: This study investigates the adaptation of SPR-I (7) into Turkish (Study-1) and the relationship between scientific reasoning, epistemological beliefs, and place of residence (Study-2). In this context, data were collected from primary school students using the survey method.

Results: The results showed that the short version of the SPR-I was within the acceptable confidence interval. In addition, the relationship between scientific reasoning and reading skills was confirmed in terms of convergent validity. Based on the data, the SPR-I had a connection to epistemological beliefs. As far as demographic variables are concerned, scientific reasoning appeared to vary according to gender, but not residential areas.

Conclusion: The structure of SPR-I (7) related to epistemological beliefs shows that it is related to beliefs about the nature of knowing and beliefs about the nature of knowledge. Based on this, educators should emphasize the development of epistemic knowledge in the development of scientific reasoning skills of young students.

KEYWORDS
Epistemic beliefs; primary school students; scientific reasoning; SPR-I (7)

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Introduction

In many countries, science education is an integral and important component of the curriculum (Achieve, Inc 2010). In the science curriculum in Turkey, children are expected to understand basic science principles and know the process of knowledge creation from primary school onwards (Ministry of National Education 2018). Scientific reasoning is defined as children's cognitive understanding of the processes of accessing scientific knowledge and the cognitive understanding they undergo in this process (Kuhn 2011; Zimmerman 2007). 'Hands-on' scientific inquiry skills such as hypothesizing, inferring meaning, and successfully implementing the scientific process are very important in the school environment (Schlatter et al. 2021). With these skills, students are better able to understand and interpret science texts and make inferences regarding the nature of science (Mayer et al. 2014). Scientific reasoning, which has different components in different age groups, has a rapid development curve (Blums et al. 2017; Koerber et al. 2015). However, scientific reasoning includes a set of skills that are influenced by cultural structure (Köksal-Tuncer and Sodian 2018). Accordingly, language skills (Koerber et al. 2015; Osterhaus, Koerber, and Sodian 2020) and intelligence (Mayer et al. 2014), which are influenced by cultural structure, were found to be associated with scientific reasoning. This has been shown as a sign of the diversity of scientific reasoning based on individual differences (Schlatter et al. 2021). Therefore, children's scientific reasoning varies by culture.

Related studies have reported that theories on knowledge and knowing, i.e. epistemological beliefs are also related to scientific reasoning (Schiefer et al. 2019; Yang, Bhagat, and Cheng 2019). Accordingly, skills such as scientific inquiry and explanation affect one's beliefs connected to the nature of knowledge (Yang and Tsai 2010). However, just like scientific reasoning skills, these beliefs change with age and manifest themselves differently according to culture (Yang et al. 2016). Investigating the scientific reasoning skills and epistemological beliefs of students from different cultures is considered important in order to learn more about cognitive styles (Schlatter et al. 2021). To date, the scientific reasoning of students from various cultures have been examined and reported (Mayer et al. 2014; Osterhaus, Koerber, and Sodian 2020; Schiefer et al. 2019). However, no such study has been conducted on Turkish culture, which has a collectivist tradition. This cultural difference may affect students' epistemological beliefs, and thus their scientific reasoning. Understanding the scientific reasoning of students from different cultures can give educators something to reflect upon while they work to reform science education (Yang, Bhagat, and Cheng 2019). This may also guide other countries looking to develop adaptive curricula.

Purpose of the study

This study aimed to determine the scientific reasoning of Turkish students and then investigate the relationship between scientific reasoning and gender, epistemological beliefs, and residential areas. Accordingly, the study was structured as Study-1 and Study-2.

In Study-1, The Science-P Reasoning Inventory (Osterhaus, Koerber, and Sodian 2020), which was previously developed in a German sample but has yet to be adapted to

Table 1. Study design.

Study	Purpose	Instrument	Process
Study-1	Adaptation of The Science-P Reasoning Inventory into Turkish	The Science-P Reasoning Inventory (Osterhaus, Koerber, and Sodian 2020)	Validity and reliability tests
	Testing the convergent validity of The Science-P Reasoning Inventory	Reading test (Ministry of National Education 2018)	Correlational analysis
Study-2	Examining the relationship between students' scientific reasoning and gender, epistemological beliefs and residential areas	The Science-P Reasoning Inventory (Osterhaus, Koerber, and Sodian 2020), The Demographic Characteristics Form, and Epistemological Beliefs Scale (Conley et al. 2004)	Testing hypotheses (independent samples t-test and correlation tests)

different cultures, was used. It was adapted into Turkish. In Study-2, The Science-P Reasoning Inventory, whose validity and reliability were tested in Study-1, was used. Thus, the relationship between students' scientific reasoning and gender, epistemological beliefs and residential areas was examined. General information about the study design is summarized in Table 1.

Theoretical background

Scientific reasoning

Zimmerman (2007) defined scientific reasoning as the skills of experimentation, inquiry, evidence presentation, and researches that result in scientific understanding or conceptual change. Pedaste et al. (2015) described it as a set of cognitive skills that include the process of hypothesizing and testing, experimenting, interpreting data, and drawing conclusions. Accordingly, scientific reasoning can be expressed as a cyclical process that involves a change operating within people who employ cognitive skills (Schiefer et al. 2019). Some of these skills develop and become more complex with age (Köksal-Tuncer and Sodian 2018; Sandoval et al. 2014). Studies conducted in the last 20 years have shown that scientific reasoning is already present in children, but they initially have a rather naive attitude toward science (Krummenauer and Kuntze 2019; Kuhn 2011; Lazonder et al. 2021; Mayer et al. 2014). However, it has also been reported that children at the primary school level perceive science more as an activity rather than a means of explaining particular phenomena (Koerber et al. 2015). For this reason, the primary school level is considered a very sensitive period in terms of scientific reasoning (Koerber and Osterhaus 2019; Van de Sande et al. 2019). With the educational content offered in this period and the developing cognitive structure, the naive attitude toward science gradually evolves into a more sophisticated understanding of science (Blums et al. 2017). Therefore, determining the scientific reasoning of children in this period with reliable tools and revealing related factors is also important in terms of clarifying attitudes towards science.

Levels of scientific reasoning

In primary school, scientific reasoning shows *conceptual and cognitive development* (Osterhaus, Koerber, and Sodian 2020). Koerber et al. (2015) reported that scientific reasoning is significantly related to intelligence and language development in a study conducted with children. Osterhaus, Koerber, and Sodian (2017) linked the development of intelligence and language skills with understanding the nature of science. However, considering the effect sizes and explained variance ratios in the relevant studies, it was underlined that scientific reasoning has a separate developmental level from *intelligence and language development* (van der Graaf, Segers, and Verhoeven 2016).

According to Kuhn (2002), children can skillfully distinguish between hypothesis and evidence regarding *conceptual development*. Again, according to Osterhaus, Koerber, and Sodian (2017), students can use their scientific reasoning during experiments. This indicates that scientific reasoning and the development of conceptual understandings of the nature of science are parallel (Osterhaus, Koerber, and Sodian 2020). Therefore, scientific reasoning can progress just like cognitive and conceptual development. This progress has led to identifying levels of understanding in explaining scientific reasoning. Sodian et al. (2002) evaluated scientific reasoning with naïve, intermediate, and advanced levels of understanding. Osterhaus, Koerber, and Sodian (2020) used these three levels of understanding to evaluate the Science-P Reasoning Inventory. Pure realism, where hypothesis and evidence are not represented as two epistemologically distinct entities, represents the naïve level of understanding. Intermediated, where the relationship between hypothesis and evidence is beginning to be understood but without a clear metaconceptual understanding of these terms. A developed hypothesis-evidence relationship reflects an advanced level of understanding

The science-P reasoning inventory

Different formats and instruments have been used to assess children's scientific inquiry. These instruments include written tests to measure procedural understanding (Roberts and Gott 2004), reasoning skills scales (Weld, Stier, and McNew-Birren 2011), inquiry skills questionnaires (Mason 2016), and aptitude tests (Sirum and Humburg 2011). However, few studies have developed paper-and-pencil tests for such a purpose (Koerber et al. 2015; Mayer et al. 2014). Although paper-and-pencil tests have been criticized for limited validity and problems with the assessment of qualitative processes (Mason 2016), they are still used as the most effective and simple tools for measuring scientific inquiry skills in school settings (Schiefer et al. 2019). In this direction, a group of researchers recently developed a paper-and-pencil test to assess different dimensions of scientific inquiry (Osterhaus, Koerber, and Sodian 2020). This tool took into account children's cognitive and conceptual development. Named the Science-P (rimary School) Reasoning Inventory (SPR-I), the instrument grounds children's understanding in the context of the hypothesis-evidence relationship. In addition, SPR-I evaluates student responses in the dimensions of experimentation, data interpretation, and understanding the nature of science at naïve, intermediate, and advanced levels. In this study, SPR-I was used to measure students' scientific inquiry levels.

Epistemological beliefs

Epistemological beliefs are defined as one's knowledge about the nature of knowledge and the process of reaching scientific knowledge (Lederman 2007). Processes that seek knowledge and understanding as to the nature of knowledge are considered metacognitive skills that regulate cognitive behaviors such as reasoning, problem-solving, and decision-making (Greene, Sandoval, and Bråten 2016; Schommer 1993). Epistemological beliefs include the dimensions of certainty, source, development, and justification of knowledge (Conley et al. 2004). Justification and source dimensions of epistemological beliefs are related to the nature of knowledge. Beliefs in the source dimension do not contain a complex structure, and individuals in this dimension produce knowledge not through research strategies but with the help of an external authority. Those categorized within the justification dimension use the data they obtain, especially through experiments that support their claims. Individuals in the certainty dimension have a weak view of the nature of science. Moreover, people who operate from this dimension may claim that scientific knowledge is certain and unchanging. On the other hand, someone in the developmental stage may state that scientific knowledge is changeable (Peffer and Ramezani 2019).

Epistemological beliefs are also known as beliefs about the nature of knowing and knowledge (Conley et al. 2004). Understanding the nature of science refers to understanding what science is, how it works and how scientific knowledge is produced (Lederman 2007). An understanding of the nature of science includes not only science as a set of facts but also the nature of science, its boundaries, methods, basic principles and values of scientific knowledge (Abd-El-Khalick and Lederman 2000; McComas 1998a). This understanding also considers science's social, cultural and historical contexts (Alkış Küçükaydın and Gökbulut 2020).

Understanding the nature of science aims to dispel students' misconceptions about science (Alkış Küçükaydın 2018), develop scientific thinking skills, and promote critical thinking about science (Schommer 1993). At the same time, the nature of science emphasizes that science is undoubtedly not dogmatic, a continuously evolving process and that scientific knowledge can be provisional (McComas 1998b).

Understanding of knowledge refers to an approach to understanding how individuals access knowledge, the nature, and what knowledge is (Conley et al. 2004). This concept also includes issues such as how knowledge is evaluated, organized, and used (Pritchard 2014).

Knowledge understanding encourages individuals to understand thinking processes, critically evaluate, and generate solutions using knowledge (Alkış Küçükaydın 2018; Alkış Küçükaydın and Gökbulut 2020). Furthermore, knowledge understanding emphasizes that knowledge can be inherently uncertain and variable (Schlatter et al. 2021).

Empirical studies conducted at the level of these dimensions have shown that epistemological beliefs predict scientific reasoning (Schiefer et al. 2019; Yang et al. 2016, 2019). Yang and Tsai (2010) stated that students with complex epistemological beliefs are better at explaining theory and evidence. According to Zeineddin and Abd-El-Khalick (2010), the higher the epistemological beliefs of students, the higher their scientific reasoning skills. Schiefer et al. (2019) agreed that the best predictor of scientific reasoning is epistemological beliefs. Yang, Bhagat, and Cheng (2019) also found some relationships between students' scientific reasoning skills and epistemological beliefs in both Taiwan and India samples, albeit at different levels. Therefore, it is seen that scientific reasoning and epistemological beliefs are related.

Present study

Children at the primary school level can distinguish hypotheses from evidence. They can also conduct controlled experiments by manipulating variables when given a choice (Mayer et al. 2014). In addition, they can reason through the evidence presented to them in different types of knowledge (Köksal-Tuncer and Sodian 2018). Sandoval et al. (2014) reported that conceptual development regarding science can be achieved by teaching the nature of science to children in primary school. The fact of the matter is, successful interpretation of data begins to develop even before primary school (Koerber et al. 2015). Skills such as conducting experiments, collecting data, and understanding the nature of science, which constitute scientific inquiry at the primary school level, have started to develop and the level of these skills can be evaluated.

Most of the studies on science reasoning at the primary school level have been conducted with samples from Western countries (Koerber et al. 2015; Lazonder et al. 2021; Mayer et al. 2014), while a few studies have been conducted in Asia (Osterhaus, Lin, and Koerber 2023; Yang, Bhagat, and Cheng 2019). Indeed, science reasoning assessments have yet to be conducted in Turkey. This study, therefore, aimed to adapt the SPR-I, which was previously developed in the German sample and tested for validity and reliability, for the Turkish sample. The SPR-I has a total of 23 items, and the validity and reliability of a short version of 7 items were also tested. The 7-item version of the SPR-I [SPR-I (7)] was deemed appropriate due to quick administration, its adaptability to different samples, and its relationship with other variables (Osterhaus, Koerber, and Sodian 2020). However, the scores obtained from the SPR-I are evaluated together with intelligence tests or reading tests in terms of convergent validity (Koerber et al. 2015; Mayer et al. 2014; Osterhaus, Koerber, and Sodian 2020; Van de Sande et al. 2019) because it is expected that there is a relationship between scientific reasoning and language skills (Osterhaus, Lin, and Koerber 2023). Children's vocabulary knowledge is especially important for understanding the nature of science (Mayer et al. 2014). For this reason, the reading test was used in the convergent validity of the SPR-I in this study.

The related literature has presented different findings on the variability of scientific reasoning according to gender. Several studies found no relationship at all between science reasoning and gender (Koerber and Osterhaus 2019; Koerber et al. 2015; Osterhaus, Lin, and Koerber 2023), while others reported gender-based differences in primary school children (Lazonder et al. 2021). This may be due to cultural structure. Therefore, this study investigated the relationship between scientific reasoning and gender in the Turkish sample (*Hypothesis-1*). Osterhaus, Lin, and Koerber (2023) reported that scientific reasoning varies according to a student's performance, and student performance is related to location. It is understood that scientific reasoning has a structure that is affected by students' experiences (Schiefer et al. 2019; Schlatter et al. 2021). Even though Turkey has a single centralized curriculum (Ministry of National Education 2018), there are differences in practice regarding students' access to science. Primary school teachers works in the city center at the primary school level, and thanks to municipal support, students have some facilities, including laboratories. However, given the number of students in rural areas, students often do not have a primary school teacher, and school facilities lag behind those in the city center. Temporary (salaried) teachers are primarily employed in village schools and are not required to have graduated from a bachelor's degree program in classroom teaching. Therefore, we assume that the basic scientific competencies and reasoning of rural students will lag behind students' experiences in urban centers. Based on this, it is predicted that there will be a statistically significant difference between urban and rural samples in terms of science reasoning level in the Turkish sample. This is why the effect of residential areas on scientific reasoning was tested in the course of this study (*Hypothesis*-2). Finally, it was hypothesized that scientific reasoning is related to epistemological beliefs (*Hypothesis-3*). Previous studies have reported that epistemological beliefs predict scientific reasoning (Yang, Bhagat, and Cheng 2019) and that the level of scientific reasoning changes depending on epistemological beliefs (Zeineddin and Abd-El-Khalick 2010). So, this relationship was also put to the test in the Turkish sample.

Context

In Turkey, basic science knowledge is offered from pre-school to high school. Ministry of National Education (2018) emphasizes teaching scientific process skills, including observing, measuring, classifying, recording data, hypothesizing, using data and creating models, changing and controlling variables, and experimenting at primary and secondary school levels. In this context, it is recommended that different methods be used to support scientific reasoning and thinking skills in science teaching. Through joint protocols with the Scientific and Technological Research Council of Turkey (TÜBİTAK), science festivals, science fairs and nature activities are organized at the primary school level to teach students scientific methods and practice questioning knowledge. The 12th Development Plan, prepared in line with the 2053 vision, emphasizes promoting science as a priority area (Twelfth Development Plan 2024–2028).

However, apart from the curriculum, family structure and social norms influence students' scientific reasoning approaches in Turkish culture. Despite all the planning, girls see science as a male pursuit and avoid career planning in these fields (Alkış Küçükaydın, Esen, and Gürbüzer 2023). Traditional thinking patterns affect the approach to scientific inquiry in education (Schwartz 2009).

Using scientific literature is important in developing students' scientific reasoning (Díaz et al. 2023). However, there are deficiencies in the accessibility of scientific literature and in teaching students how to use this literature in Turkish schools (Esen, Türkyılmaz, and Alkış Küçükaydın 2022). An example is the problem of teaching critical thinking skills, which are considered a prerequisite for scientific reasoning (Yeşilyurt 2021). The same problem is encountered in teacher training that will provide this knowledge (Önal and Erişen 2019).

In addition to these, students' socio-economic background, the educational level of their families and environmental factors are also influential in developing scientific reasoning (Esen, Türkyılmaz, and Alkış Küçükaydın 2022; Alkış Küçükaydın, Esen, and Gürbüzer 2023). Activities such as conducting experiments, participating in scientific activities, taking a technical trip or following a scientific career are not accessible to students in the countryside (Güngör and Koçbeker Eid 2021). All these prevent the formation of an understanding of the nature of science, which is necessary for scientific reasoning (Kocagül Sağlam 2019). In Turkey, opportunities for developing science process skills, including data collection and hypothesizing skills, vary depending on where children live. Despite curriculum updates, science is not an easily accessible field for students who cannot continue their education in the city centre or college. Therefore, unlike the Western sample, the study deals with the scientific reasoning of children in Turkish society and discusses in terms of the residence and epistemological beliefs.

Study 1: Adaptation of the SPR-I (7) Scale

Participants

The participants of the study were primary school students studying in the Central Anatolia Region of Turkey. A purposive sampling technique was used to reach students from rural and city centres. In this context, the number of schools in rural areas and city centres was determined by obtaining the necessary permissions in Ankara, one of the big cities in the Central Anatolia Region. Then, the questionnaires were delivered to the primary school teachers with the permission of the school administrations. The questionnaires were completed by the students with parental consent under the supervision of the primary school teachers and delivered to the researchers. In this context, data were collected from only one region of Turkey. The age range of the students was 9–13 years ($M = 10.81$, $SD = 1.19$). In Turkey, students start primary school at the age of 7. However, they can start later if their parents wish. In addition, unsuccessful students can repeat a grade, which may lead some students to finish primary school later. A small number of children aged 12 ($n = 12$) and 13 ($n = 9$) participated in this study. However, this led to a widening of the age range.

The study included 201 girls (47.3%) and 224 boys (52.7%). Of the students, 113 (26.6%) lived in the city center and 312 (73.4%) lived in rural areas. All the students were subject to a single curriculum applied across Turkey. Therefore, their educational experiences were thought to be quite similar. Within the scope of the study, data were collected from one school in the city center and two schools in rural areas. In the city center, students come from similar socioeconomic backgrounds, and the educational profiles of parents are similar. In rural areas, data were collected from two neighbouring neighbourhood schools, and the socioeconomic conditions of these schools are similar. The parent profile in both schools is the same, and the mothers of the children are housewives. Fathers are usually workers or civil servants. Therefore, the students have a culturally parallel structure.

Instruments

SPR-I (7) scale

SPR-I (7) was developed by Osterhaus, Koerber, and Sodian (2020) for primary school students in a German sample. It aimed to measure primary school students' knowledge of experimentation, data interpretation, and understanding the nature of science. The instrument is a paper-and-pencil test administered face-to-face. SPR-I (7) has 3 items in the nature of science dimension, 1 item in the data interpretation dimension, and 3 items in the experimentation dimension. A sample of the items is presented in Figure 1.

In SPR-I (7), all items are scored in 3 categories: naïve (0 points); intermediate (1 point); and advanced (2 points). The student response to each question is evaluated, and then an appropriate score is given (Figure 2). The scoring of the SPR-I (7) is done manually

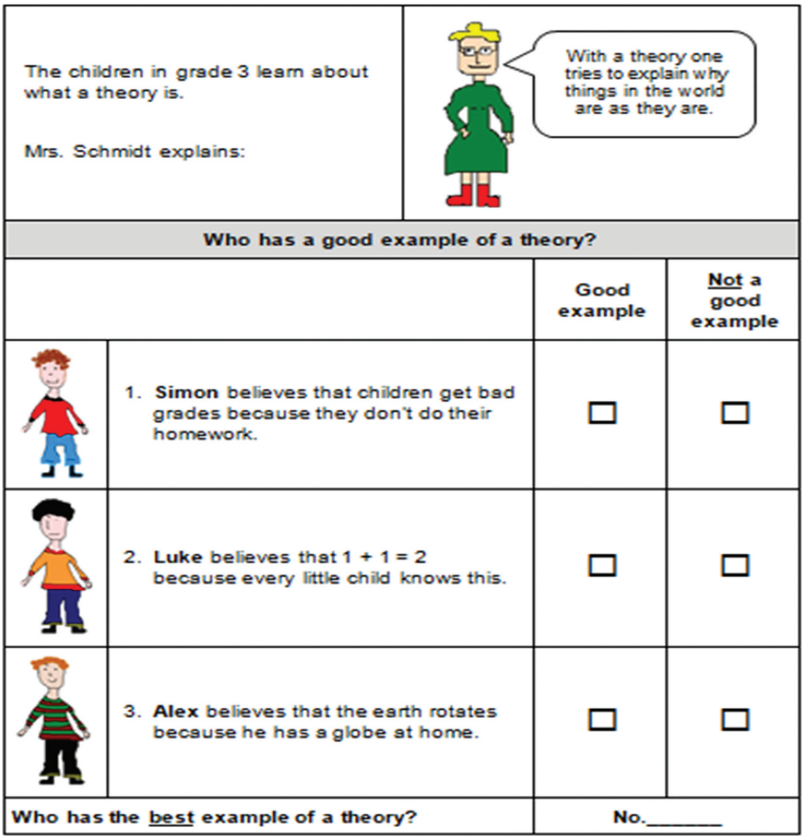

Figure 1. SPR-I (7) sample item.

Item		Answer	Yes	No			
5	A	**Simon** believes that children get bad grades Because they don't do their homework.	2.4	2.1			
	N	**Luke** believes that 1 + 1 = 2 because every little child knows this.	0.1	0.3			
	I	**Alex** believes that the earth rotates because he has a globe at home.	1.2	1.6			
				Sum			
Remarks:					3.4	0	
					3.6	1	
					3.7	0	
					3.8	0	
					3.9	1	
					4.0	0	
					4.1	0	
					4.3	2	
						Final level	

Figure 2. SPR-I (7) scoring Guide.

according to the scoring guidelines (for more information, see Osterhaus, Koerber, and Sodian 2020).

Reading test

Intelligence and/or reading tests are used together in the evaluation of the SPR-I (7) scale (Koerber et al. 2015; Mayer et al. 2014) because it is known that scientific reasoning skills are related to intelligence development and reading proficiency (Lenhard and Schneider 2006). However, in Turkey, intelligence tests are not open to the use of all researchers and are only conducted under the supervision of institutions that have a certificate of practice in this field. Therefore, in this study, the reading test was used to evaluate the convergent validity of the SPR-I (7). To achieve this, 20 multiple-choice reading tests were prepared by considering the reading and comprehension framework by the Ministry of National Education (2018). Item analysis of the test was conducted using the Test Analysis Program (TAP.exe). Accordingly, the item analysis findings of the test are as follows: rjx = .45, pjx = .69, Kuder Richardson-20 = .72, and Kuder Richardson-21= .67, Cronbach's alpha = .72 (Tekin 1991).

Procedure and data collection

Ethical procedures were fulfilled before the implementation of SPR-I (7). First, permission was obtained from the responsible author of the SPR-I (7), and then the application permission was obtained from Dicle University University Ethics Committee (Ref.-180). For the application of the Turkish version of the SPR-I (7), school principals were contacted and the authors of the study administered it to the students face-to-face in the classroom environment. The SPR-I (7), personal information form, and other questionnaires were combined into a single application form. After the parental permission form and voluntary consent form were obtained, the application was carried out for two lesson hours. SPR-I (7) and personal information forms were administered in the first class hour, and other questionnaires and tests were administered in the second class hour. Data were collected at the beginning of the 2023–2024 academic year.

Certain steps were followed in the adaptation of SPR-I (7) into Turkish. First, the SPR-I (7) was translated into Turkish by the study team. Then, two interpreters fluent in both Turkish and English were asked to translate the SPR-I (7) into Turkish. The statements from the translators and the translated statements of the study team were evaluated in a mini-panel. The names in SPR-I (7) were translated into Turkish. For example, 'Mr. Mesut' was used instead of 'Mr. Miller' and 'Village Herbmeadow' was replaced with 'bitki çayırı köyü'. There is no item or expression in the scale that is incompatible with Turkish culture. Therefore, remaining faithful to the nature of the original scale, only the names of people and places were changed in accordance with the Turkish language. The back-translation of the SPR-I (7) into Turkish was done by two other native English translators. The new English version of the SPR-I (7) was evaluated by the study team and compared with the original version of the scale. Finally, the SPR-I (7) was finalized with the help of two experts in the field of Turkish language (see Appendix 1). The SPR-I (7) adapted to Turkish was subjected to a pilot study with a different sample of participants. In the pilot study, eight students between 9–13 years of age read the SPR-I (7) and commented on its comprehensibility. After the comments and evaluations were received from the students, the Turkish version of the SPR-I (7) was finalized and made ready for implementation.

Data analysis

Data were analyzed with R Core Team (2021) and the partial credit model (Masters 1982) was applied to test the unidimensionality (Osterhaus, Koerber, and Sodian 2020). The partial credit scoring structure of the items that makes up the SPR-I (7). SPSS 26 program was used for descriptive analysis and correlation analysis of the data.

Study 2: The Relationship of Scientific Reasoning with Gender, Residential Areas and Epistemological Beliefs

Method

In this part of the study, the Turkish version of SPR-I (7) was used to make group comparisons according to students' demographic characteristics and epistemological beliefs.

Participants

The participants of the study were the students in Study-1.

Instruments

The demographic characteristics form

To examine the variables related to scientific reasoning skills, students were asked to provide information on age, gender, and area of residence. The latter was classified as either urban or rural.

Epistemological beliefs scale

The self-report scale developed by Conley et al. (2004) was used to determine students' epistemological beliefs. The scale, adapted into Turkish by Özkan (2008), consists of source (5 items), certainty (9 items), development (6 items), and justification (6 items) sub-dimensions. Conley et al. (2004) stated that the four dimensions of the scale represent two general areas discussed by Hofer and Pintrich (1997) as the basis of individuals' epistemological theories: beliefs about the nature of knowing and beliefs about the nature of knowledge. According to the beliefs about the nature of knowing dimension, individuals see knowledge as originating from external authorities outside the self. In addition, this dimension includes the role of experiments and the use of data to support arguments (Schommer 1990). Beliefs about the nature of knowledge dimension include the individual's beliefs about the nature of knowledge. Accordingly, this dimension includes the belief that science is an evolving subject and that ideas and theories can change based on new data and evidence. Beliefs in this dimension are more sophisticated. Therefore, the idea that ideas in science can change is included in this dimension (Hofer 2000). Consequently, the source and certainty dimensions of the scale are related to beliefs about the nature of knowing. Development and justification sub-dimensions are related to beliefs about the nature of knowledge. There are 26 questions in total on the 5-point Likert scale (1=strongly disagree; 5=strongly agree). Items in the source and certainty dimensions are reverse-coded, with higher scores reflecting more complex epistemological beliefs.

Data analysis

The variables thought to be related to SPR-I (7) were tested for this section of the study. First, descriptive analyses of the epistemological beliefs questionnaire were conducted. Skewness and kurtosis values of the scale are between −1.05 and −1.04. It was accepted that the values obtained supported the assumption of normal distribution (Tabachnick and Fidell 2013) and the hypotheses were tested. The equality of variances in the scores obtained from the scales was checked with Levene's test. The scores from the students' demographic information were analyzed with independent-samples t-test. In addition, the independent samples t-test was used to analyze whether the students' scientific reasoning changed according to their place of residence. Correlation analysis was used to compare the scores obtained from the SPR-I (7) and the epistemological beliefs scale.

Results

Core performance

The distribution of students' responses to SPR-I (7) at item level is presented in Table 2. The results show that the most frequently naïve item is A02: Airplane (64.7%), which constitutes the experimentation dimension in SPR-I (7). The most frequently answered item at the intermediate level was A11: Mistakes in science, which measures the nature of science dimension (48.2%). The most frequently answered item at the advanced level is A06: Witch (23.5%), which is in the data interpretation dimension.

It was observed that students gave answers at the naïve level in 2.86 (40.9%) of the 7 items, at the intermediate level in 2.32 items (33.17%) and at the advanced level in 1.16 items (16.6%). According to the answers given, the mean score (0- naïve, 1- intermediate, 2- advanced) obtained from SPR-I (7) was 22.15 ($SD = 4.99$, median = 12.60, min = 1.74, max = 23.50).

Table 2. Descriptive statistics for SPR-I (7).

	Frequency (%) of children's scores, for the naïve (0), intermediate (1), and advanced level (2)		
Item	naïve	intermediate	advanced
A02: Airplane	64.7	21.2	14.1
A03: Middle Ages	57.4	28.5	14.1
A05: Theory	48.9	30.1	20.9
A06: Witch	58.4	18.1	23.5
A08: The aardvark	38.1	45.6	16.2
A10: Planet Lila	44.0	40.5	15.5
A11: Mistakes in science	39.5	48.2	12.2

Scale analysis

In order to test the structure of SPR-I (7), one-dimensional partial credit model was applied to the 7 items in the scale. According to the results of the analysis, all items of the SPR-I (7) showed a good fit to the model: MLE person-separation reliability = .43, WLE person-separation reliability = .40, EAP/PV reliability = .47, and all infit and outfit fit statistics being close to 1 (Table 3). In addition, Cronbach's alpha coefficient of SPR-I (7) was calculated and found to be .82.

Table 3. Item fit statistics for the SPR-I (7).

	Item Mean	Measure	S.E. Measure	Infit	Outfit	Point biserial
A02: Airplane	0.49	0.4415	0.0821	1.107	1.121	0.464
A03: Middle Ages	0.56	0.2409	0.0789	1.122	1.043	0.436
A05: Theory	0.72	−0.1398	0.0746	1.030	0.987	0.526
A06: Witch	0.65	0.0249	0.0762	1.108	1.036	0.561
A08: The aardvark	0.78	−0.2824	0.0736	0.986	1.023	0.413
A10: Planet Lila	0.71	−0.1286	0.0747	0.823	0.808	0.550
A11: Mistakes in science	0.72	−0.1564	0.0745	0.848	0.873	0.458

Correlational analysis

The relationship between the dimensions of SPR-I (7) and the reading test was also examined (Table 4). There appeared to be a significant relationship between the dimensions of SPR-I (7), namely experimentation ($r = .10$, $p < .05$) and nature of science ($r = .20$, $p < .001$), and reading skills. There was also a relationship between the total score obtained from SPR-I (7) and reading skills ($r = .18$, $p < .001$). However, no significant relationship was found between data interpretation and reading skills ($r = .09$, $p > .05$).

Table 4. Correlation between SPR-I (7) dimension and reading skills.

	Reading skills	Experimentation	Nature of science	Data interpretation
Reading skills	–			
Experimentation	.10*	–		
Nature of science	.20**	.32**	–	
Data interpretation	.09	.29**	.29**	–

*p<.05, ** p < .001.

Hypothesis tests

Hypothesis 1

The scores of the students on the dimensions of SPR-I (7) were evaluated according to their gender. Aside from the data interpretation dimension ($t_{(423)} = 1.86$, $p > .05$), a significant difference was observed in the other two dimensions according to gender. In the experimentation ($t_{(423)}=$ 2.18, $p < .05$) and nature of science ($t_{(423)}=$ 3.46, $p < .05$) dimensions of SPR-I (7), girls scored higher than boys (M_{girls} =.71, *SD*=.15; M_{boys}=.61, *SD*=.14 for experimentation; M_{girls} =.75, *SD*= .15; M_{boys}=.59, *SD*=.14 for nature of science).

Hypothesis 2

The scores of the students on the dimensions of SPR-I (7) were evaluated according to the place of residence. According to the results of independent sample t-test, no significant difference was found in any dimension of SPR-I (7) according to the place of residence ($t_{experimentation}(423) = -.71$, $p > .05$; $t_{nature\ of\ science}(423) = .03$, $p > .05$; $t_{data\ interpretation}(423) = -3.27$, $p > .05$).

Hypothesis 3

Finally, the relationship between SPR-I (7) and epistemological beliefs was tested. It was observed that each dimension of SPR-I (7) was positively correlated with the total score obtained from the epistemological beliefs scale ($r_{experimentatipn} = .11$, $p < .05$; $r_{nature\ of\ science} = .16$, $p < .05$; $r_{data\ interpretation} = .16$, $p < .05$).

Discussion

In this study, the SPR-I (7) was adapted for a Turkish sample and its relationship with reading skills was tested. The findings show that the SPR-I (7) has a unidimensional structure and that the scientific reasoning skills of primary school students can be assessed at the naïve, intermediate, and advanced levels. The relationship between SPR-I (7) and reading skills in terms of convergent validity was also discussed. In previous studies, it was confirmed that the correlation values obtained between SPR-I (7) and reading skills were accepted at the level obtained in this study (Koerber and Osterhaus 2019, 2021). Therefore, the relationship between scientific reasoning and reading skills points to the need for children to master science-specific vocabulary (Osterhaus, Lin, and Koerber 2023). However, no significant relationship was found between all dimensions of SPR-I (7) and reading skills. The relationship between data interpretation and reading skills is not significant. This may be related to both the nature of data interpretation itself and the number of questions. Data interpretation is seen as a skill that is difficult to acquire in young children (Osterhaus, Lin, and Koerber 2023). Therefore, it may be related to a different construct (e.g. intelligence or development) than reading skills. However, there was only one data interpretation question in the SPR-I (7). This may not have been sufficient in terms of measurement. Based on this, the SPR-I (7) should be expanded with deeper data interpretation questions.

SPR-I (7) is important in terms of explaining the conceptual development model of scientific inquiry (Koerber et al. 2015; Köksal-Tuncer and Sodian 2018). The level of scientific inquiry can be examined at three levels (naïve, intermediate, and advanced). The validity of these levels was supported by point biserial correlation and partial credit model. However, based on the findings obtained from the SPR-I (7), it should be noted that item discrimination was good (Table 3), especially in the experimentation dimension, where most of the students remained naïve (64.7%). This finding is in line with the results of previous studies (Osterhaus, Koerber, and Sodian 2020).

Based on an analysis of the findings, the SPR-I (7) was deemed valid and reliable in the Turkish sample. Since there is not yet a measurement tool to assess scientific inquiry in the Turkish literature, no comparison can be made on the use of SPR-I (7).

The study used SPR-I (7), the shortened version of SPR-I. Osterhaus, Koerber, and Sodian (2020) applied all of the validity and reliability analyses for SPR-I to SPR-I (7). In this study, the convergent validity of SPR-I (7) was assessed with a reading test. This shortened version can assess students' scientific reasoning skills and can be used economically in various research settings, such as intervention studies. It is also a very useful tool for teachers. By using fewer items, scientific reasoning can be assessed in a more focused and effective way. Researchers can more easily determine whether these basic concepts have been assimilated and whether the basic principles of science have been grasped.

However, SPR- I (7) consists of 7 items (3 related to NOS, 3 related to the experiment, and 1 related to data interpretation). As mentioned, this may not adequately address the full range of scientific reasoning skills. Moreover, it may prevent in-depth thinking about the components of scientific reasoning. Therefore, this may limit the applicability of the findings to other contexts. However, we still need an alternative Turkish measurement tool to the SPR-I (7). Therefore, this study, which tested the reliability and validity of SPR-I (7), cannot provide information about the scope of SPRI (7). This may be questioned in the future in Turkish literature, where scientific reasoning skills have been tested for the first time. In Study-2, students' scientific reasoning skills were evaluated in terms of gender, place of residence, and epistemological beliefs. The findings showed that girls had higher scientific reasoning scores than boys. However, this finding is contrary to previous literature. While some literature did not find a significant difference between girls and boys (Koerber et al. 2015; Osterhaus, Lin, and Koerber 2023), Lazonder et al. (2021) noted that boys scored higher. Needless to say, analyzing the reasons behind this difference would give more clarity into the overall issue.

Studies focusing on gender differences have reported that boys show a greater interest in science (Hyde and Linn 2006; Reilly, Neumann, and Andrews 2015). In fact, they have suggested that scientific reasoning skills are related to this interest. Suggestions have been made to education policymakers calling for a similar interest to be aroused in girls. It seems that girls in the Turkish sample are quite good at scientific reasoning skills. This can be considered a product of the recent efforts to prevent gender inequality in science in Turkey. Of course, variables such as teacher approach, family support, and science capital have an impact. In addition, a situation arising from the sample in the study may have emerged. The best way to understand this is to conduct a study with larger and different samples and compare the results with the SPR-I (7), which was introduced to the Turkish literature for the first time and assesses scientific reasoning. Furthermore, this finding has only compared with the Western sample. The literature can be expanded with different study findings from the east countries.

In addition to, the fact that there is no significant difference in the data interpretation dimension is likely related to the difficulty of acquiring this skill for both genders in this age group (Lazonder et al. 2021). Lazonder and Kamp (2012) stated that the ability to hypothesize or make predictions develops very little between first and sixth grade, and that data interpretation is delayed. For the development of data interpretation skills, it is necessary to recognize the characteristics of data and visual reading (Krummenauer and Kuntze 2019). Therefore, a significant difference could not be obtained at the gender level due to the lack of these skills' development.

Previous literature has reported that students in urban centers have more educational opportunities and that this affects scientific reasoning skills (Osterhaus, Lin, and Koerber 2023). However, this finding was not supported in the current study. We think there are two reasons for this. First, the current education system in Turkey could play a role in this. The implementation of similar curricula in rural and urban centers and the related content knowledge may have eliminated the differences in students' scientific reasoning skills. Inequality of opportunity may have been reduced with recent investments in rural education and teacher employment. The other reason may be explained by the fact that the growth spurt shown by rural and urban students is not always linear. According to Fischer (2008), in both cases, whether rural or urban, the learning conditions at school do not meet the needs of 43% of children. In this case, even if rural students are initially mediocre, they can show great improvement over time and in the following years. Students in the city center may also make good progress at the beginning but not much over time. This is considered normal for this age group (Schwartz 2009). Therefore, scientific reasoning does not always progress linearly. Location may not be very meaningful in this respect.

Finally, scientific reasoning was found to be positively related to epistemological beliefs. This supports previous literature (Schiefer et al. 2019; Zeineddin and Abd-El-Khalick 2010). Epistemological beliefs include beliefs about the certainty of knowing and the source of knowledge (Hofer and Pintrich 1997). These beliefs are essentially evaluated within cognitive activities, as they are predictors of conceptual understanding, reading, and learning approaches (Tsai et al. 2011; Yang et al. 2016). Scientific reasoning also includes cognitive activities such as knowledge acquisition, hypothesis formation, and data interpretation. Therefore, scientific reasoning seems to be related to epistemological beliefs in terms of content and structure. Suffice it to say, those with more complex epistemological beliefs are expected to be better at hypothesizing, interpreting data, and possessing knowledge regarding the nature of science.

Limitations and implications

The study has some limitations. First, it was conducted only with primary school students in a certain region of Turkey. Therefore, it may be inconvenient to generalize the findings to all Turkish children. There were also not an equal number of students between rural and urban centers, so the observed differences in scientific reasoning may not be fully represented. Moreover, even in urban centers, students' own internal dynamics (e.g. school resources, family support, etc.) may differ. Therefore, we suggest that these should be taken into account in future studies.

The other limitation of the study is related to the structure of the SPR-I (7) itself. As Osterhaus, Koerber, and Sodian (2020) pointed out, the SPR-I (7) is a tool that can offer practical implications for group work rather than individual diagnoses and assessments. Therefore, unlike epistemological beliefs, it can be useful in studies comparing students' views on the nature of science or scientist image with scientific reasoning skills.

In addition, the study's results were compared with those of other studies, which were often in different directions. This situation is due to the limited number of studies conducted with young age groups in scientific reasoning and cultural differences. Therefore, it is seen that the methodological structure of these studies is different. For this reason, the results of this study also have methodological limitations.

Finally, it is worth noting that the study's most significant limitation is the number of items in the SPR-I (7). Although the validity and reliability of the original scale and its Turkish version have been established, increasing the number of items in future studies may be a good idea.

Conclusion

The study showed that the SPR-I (7) is a valid and reliable instrument in the Turkish sample. However, items can be added to strengthen the data interpretation dimension of the SPR-I (7). The structure of SPR-I (7) related to epistemological beliefs shows that it is related to beliefs about the nature of knowing and beliefs about the nature of knowledge. Based on this, educators should emphasize the development of epistemic knowledge in the development of scientific reasoning skills of young students.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon request.

Ethics approval

This study was approved by the ethics committee of the Dicle University (2 August 2023/-539904).

Consent to participate

Informed consent was obtained from all individual participants included in the study.

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