EXAMINING OF 7th GRADE STUDENTS' SCIENTIFIC REASONING SKILLS

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Abstract: One of the main objectives of science education is to improve students' levels of scientific literacy. Being one of the general thinking skills, scientific reasoning plays an important role in doing science, forming scientific concepts, and in the success of science education and Science, Technology, Engineering and Mathematics (STEM). In this context, the aim of this study was to examine the scientific reasoning skills of 7th grade students. The sample of the research was composed of 230 7th grade students. Classroom Test of Scientific Reasoning, developed by Lawson (1978, 2000) and translated to Turkish by Ateş (2002), was used to collect data. In this study, among 12 translated questions, a total of 9 questions were used to measure the cognitive properties (2 being related to concrete thinking and 7 to abstract thinking). In the test, students were first asked to choose the best answer from the choices regarding the questions related to a given situation, and then explain why they chose those answers. Students could get points in the test from 0-9, with one (1) point given if both the answer and the explanation of each problem were correctly selected. Data were evaluated using descriptive statistical analysis techniques via the SPSS program. When the total scores from the test were evaluated on a question-based basis, it was seen that the respondents mostly answered the first question on the conservation of the mass correctly while they answered the seventh question requiring the control of the variables with the lowest percentage. The data analysis revealed that the participant students' abilities of proportional thinking, determining and controlling variables, hypothetical thinking and correlational thinking -which are the expected characteristics of abstract process period- were lower than expected.

Keywords*:* middle school students, science education, scientific reasoning skills

INTRODUCTION

One of the main objectives of science education is to improve the scientific literacy levels of students (Bybee & McCrae, 2011; Ministry of National Education [MoNE], 2013; National Research Council [NRC], 2012). However, according to the 2015 PISA Turkey

National Report, Turkey is below the average score for all participating countries in the field of science literacy (PISA, 2015). Scientific literacy is generally described as the ability to make conscious decisions on issues based on science and technology, and is linked to scientific concepts, processes of scientific research, and in-depth understanding of the nature of science (Bell, Blair, Crawford, & Lederman, 2003). One of the main skills focusing on acquiring is high-level thinking skills as well as the content of science for students' scientific literacy development. Science education in schools should contribute to educating students with high-level thinking skills necessary for the 21st century (Osborne, 2013). Scientific thinking, one of the general thinking skills, plays a crucial role in making science, forming scientific concepts, and the success of science education (Lawson, Clark, Meldrum, Falconer, Sequist, & Kwon, 2000, Lawson, Banks, & Logvin, 2007), and science, technology, engineering and mathematics (STEM) (Ding, Wei, & Mollohan, 2016). Scientific thinking is the process by which the logic principles are applied to scientific processes - to explain, to create hypotheses, to make estimates, to solve problems, to design and perform experiments, to identify and control variables, to analyze data – in oder to develop an understanding (Hanson, 2016), the ability to think like a scientist while evaluating the quality of scientific evidence (Drummond & Fischhoff, 2015), and to seek knowledge (Kuhn, 2010). Scientific reasoning is based on knowledge of the content of science, knowledge of scientific processes and epistemic knowledge (Kind & Osborne, 2017). Scientific thinking and reasoning depends on cognitive development. The stages of cognitive development corresponding to primary and secondary schools are the stages of concrete and abstract (formal) operational processes. It is expected that students to be developed the characteristics of conservation (matter, mass, volume, etc. conservation) of concrete operational stage. In the formal operational stage, it is expected that students to be developed the skills of hypothetical thinking (if ... and if ... happens), identifying and controlling variables, proportional, probabilistic, combinatorial, and correlational thinking (Lawson, 1978; Senemoğlu, 2005). Based on Zeidler and Lewis's study (2003), the summary of the cognitive stages as one of the interdependent developmental attributes affecting scientific literacy is presented in Table 1:

Table 1

Cognitive stages and the outcomes expected from the students

Cognitive Stage	Outcomes expected from students
Concrete operational and transtional thinking	• Serial reasoning • Concrete reversibility • Establishing correspondence and inverse correspondence between sets of (concrete) variables
Formal operational thinking	• Hypothetico-deductive reasoning • Systematic control of multiple variables • Probabalistic reasoning • Proportional reasoning • Correlational reasoning • Combinatorial reasoning • Propersitional logic

According to the results of the study by Ding, Wei and Mollohan (2016), it is interesting to note that the scientific thinking skills of students regardless of university or major show little change during the 4 years of undergraduate education. In the light of this result, it is seen that the development of scientific thinking skills at earlier ages and during the education periods of the students is important. As cited by Chen and She (2015), scientific thinking and reasoning skills can be transferred and educated. The measurement of scientific thinking is also the essence of effective science education (Osborne, 2013). For this reason, it is important for educators to measure students' scientific reasoning skills in order to be aware of the levels of the students. In this context, the aim of this study is to examine the level of scientific reasoning skills of 7th grade students who are studying at central middle schools in a province in western Turkey?

METHOD

In the study, survey research method is used from quantitative research methods. "In survey research, investigators ask questions about peoples' beliefs, opinions, characteristics, and behavior. … Survey research typically does not make causal inferences but, rather, describes the distributions of variables in a specifed group" (Ary, Jacobs, Sorensen, Razavieh, 2010 p. 372). The sample of the study consisted of 230 7th grade students who are studied at the central middle schools in the province of western Turkey in the 2016-2017 academic year.

The sample of the study was composed according to the method of convenience sampling that is easily accessible from the nonrandom sampling methods in order to save time. Convenience sampling is choosing a sample based on availability, time, location, or ease of access (Ary, Jacobs, Sorensen, Razavieh, 2010 p. 431).

Tool to collect data

Classroom Test of Scientific Reasoning (CTRS), which was developed by Lawson (1978, 2000) and translated to Turkish by Ateş (2002), was used as collect data. The test includes 6 subscale of conservation of mass and volume; reasoning of proportional, probabilistic, correlational and combinatorial; identification and control of variables. The test consists of 12 paired items designed in a "two- tier" type multiple-choice format to illustrate problem scenarios (Ates & Cataloglu, 2007). The first tier focuses on the content question of related scenario, and the second tier includes reasons on why the first answer is correct. In this study, among 12 translated questions, a total of 9 questions were used to measure the cognitive properties (2 is related to concrete thinking and 7 to abstract (formal) thinking). Regarding the questions in the test items, we met 3 science teachers who have 30, 7 and 15 professional carrier years. According to their opions, 3 questions of probabilistic and combinational thinking skills were not suitable for 7th grade students, and they were drawn from the test. The characteristics of the measuring instrument used are shown in Table 2.

Table 2

The characteristics of the measuring instrument

Cognitive Stage	Characteristics	Question Number
Concrete operational stage	Mass conservation Volume conservation	1 2
Abstract (formal) operational stage	Proportions Identification and control of variables Correlational thinking	3-4 5-6-7-8 9

Students could get points in the test from 0-9, with one (1) point given if both the answer and the explanation of each problem were correctly selected. If both an incorrect answer and an inadequate explanation were provided, the items were scored of zero (Ates & Cataloglu, 2007). The reliability of the test (KR-20) was calculated as 0.78 by Lawson (2000). The reliability of the Turkish version of the CTSR (KR-20) was found to be by Ates and Cataloglu (2007). In the analysis carried out in this study, the reliability of the test (KR-20) was found to be 0.55. It is thought that the small number of questionnaires affects the

reliability of the test negatively. The CTRS test was administered to 8th, 9th and 10th grade students by Lawson (Lawson, 1978, Lawson et al., 2000; Lawson, Banks, & Logvin, 2007). It is seen that the version translated into Turkish is utilized to groups of students at various levels (Acar, 2015; Acar, Tola, Karaçam, & Bilgin, 2016; Ateş, 2002; Ateş & Çataloğlu, 2007; Yüzüak, 2012). The study is limited to the answers obtained from the "Scientific Reasoning Ability Test" used in 230 7th grade students and studying in the central middle schools of a province in western Turkey in the 2016-2017 academic year. It is accepted that the data obtained from the measurement tool used in the study reflect the reality.

Data Analysis

Data obtained from the study were evaluated by using descriptive statistical analysis techniques via the SPSS program. The frequencies and percentages of responses on a question-based of the participants were determined.

RESULTS

The results of descriptive statistics are displayed in Table 3.

Table 3

Statistical results from the test of reasoning skills

N	Minimum	Maximum	Mean	Std. Deviation
230	.00	7.00	1.88	1.49

Additionally, percentage distributions of participants across total scores on related reasoning skills are presented in Figure 1.

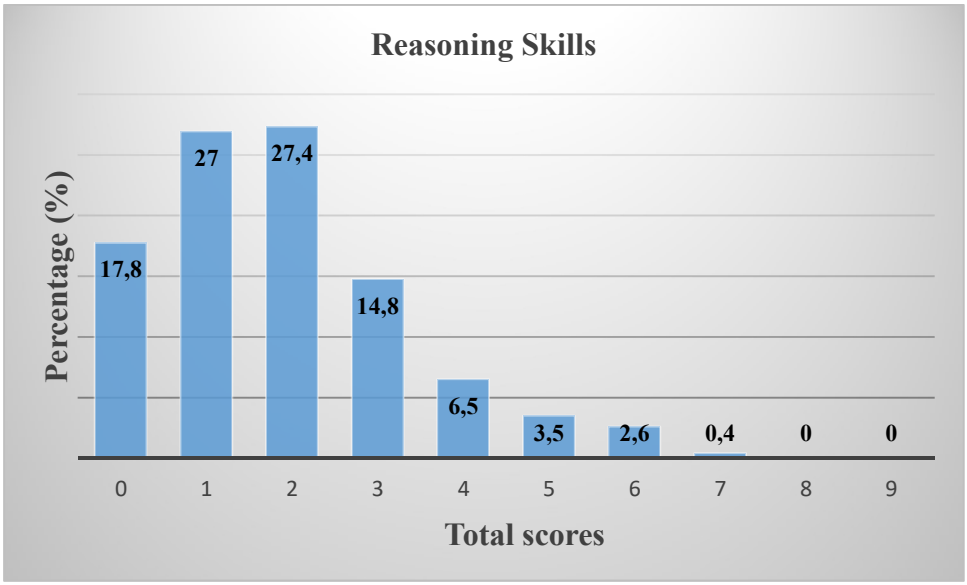

Fig. 1. The total scores and percentages of participants about resoning skills

Furthermore, the frequencies and percentages of both the correct answer of the first and second-tier of releating questions were presented on the question-based basis in Table 4.

Table 4

The frequencies and percentages of correct responses on the question-based

Cognitive Stage	Characteristics	Question Number	f	%
Concrete operational stage	Mass conservation	1	137	59.6
	Volume conservation	2	57	24.8
Abstract (formal) operational stage	Proportions	3	49	21.3
		4	10	4.3
	Controlling variables	5	90	39.1
		6	57	24.8
		7	3	1.3
		8	11	4.8
	Correlational thinking	9	19	8.3

DISCUSSION AND CONCLUSION

The reasoning levels of participants were determined. As can be seen in Table 2, the mean score of the participants is 1.8. According to the results, the participants are on avarage in concrete operational stage. Based on the statistical data on the total scores from the test (as seen in Figure 1), as the most percentage, 27.4% of the participants get 2 point, no body scored 8 and 9 point, and only 0.4% were received 7 point. Unfortunatally, 17.8% of the participants get zero. The data analysis revealed that the participant students' abilities of proportional thinking, determining and controlling variables, hypothetical thinking and correlational thinking -which are the expected characteristics of abstract (formal) operational stage- were lower than expected. Similarly, Özarslan and Bilgin (2016) revealed that 5.1% of their participants, which are 8th garde students, were in formal operational stage. Tajudin and Chinnappan's study (2015) also indicates that majority of the participating students (94%), which are secondary school students (16-17-year-olds), were going at the concrete level of scientific reasoning.

Furthermore, when the correct answers of the participants were analyzed descriptively on the question-based basis, as can be seen in Table 4, while the 59.6% of respondents with the most percentage answered correctly the first and second-tier of the 1st question including

conservation of mass, participants answered the 7th question of controlling of the variables with the lowest percentage (1.3%). On the other hand, based on Piaget's stage of cognitive development, 7th grade students, which are roughly 13-14 years old, should have developed the skills of formal operational stage (after about age 12) (Senemoğlu, 2005). It can be suggested that although the reasoning skills have placed among the aims of revised curriculum in recent years (MoNE, 2013) the expected outcomes of reasoning skills from curriculum could not be developed. The factors affecting development of reasoning skills can be discussed in other studies. Reasoning skills, at least in some students, will probably develop by getting adolescence. Besides, Shayer and Adey (1993) present dramatic evdence of positive effects as a consequence of instruction. Obtained results from the present study are also consistent with those reported by Celik and Ozdemir (2011). According to their results, more than half of the 7th and 8th grade students (60%) were not accomplished of proportional reasoning skills. Pelen (2014) stated that the proportional reasoning and classification skills of 6th grade students are moderate. The review of the literature has also shown that many secondary and high school, college and university students have not yet developed the higher order reasoning. They have difficulties in problem solving, understanding theoretical concepts, rejecting scientific misconceptions, and understanding the nature of science and mathematics because of their reasoning deficiencies (Marusic, Zorica, & Pivac, 2012; Lawson, 2004). Scientific literacy is considered a major priority in science education reform (Bybee & McCrae, 2011; MoNE, 2013, NRC, 2012). In this regard, teachers must teach students the necessary reasoning abilities to develop their scientific literacy levels (Lawson, 2004).

Seven levels of competency in the field of scientific literacy are defined in the PISA 2015 implementation. It is expected that students in the 15-year-old group, which is the target group in PISA, will have defined knowledge and skills at the 2nd proficiency level which is the basic competence level. Students at this level have daily content knowledge and basic process knowledge; to describe the appropriate scientific explanation, to interpret the data, and to determine the question to be asked in a simple experimental design. They can use basic or everyday scientific knowledge to describe a valid result in a simple dataset. They can identify basic epistemic knowledge by identifying questions that can be investigated scientifically. They can use basic or everyday scientific knowledge to describe a valid result in a simple dataset. However, in the field of science literacy, 44.4% of the students in Turkey are at level 1 and below (sub-competency level), while only 0.3% are at level 5 and above

(upper level of competence) (PISA, 2015).

It can be argued explicitly that both the PISA 2015 Turkey results and the scientific thinking skills of the students should be developed in the light of the findings obtained from this study. Although there was a relationship between reasoning with probabilities, correlations, combos and class level (Alkan & Erdem, 2009), several methods have been used to foster students' scientific thinking and reasoning skills. For example, argumantation-based teaching and learning was helpful in enhancing students' scientific reasoning (Acar et al., 2016); inquiry teaching was found effective for developing student scientific reasoning (as cited Acar, 2015; Chen & She, 2015; Daempfle, 2006). The classroom environment providing opportunities students to resoning via ill-structured problems influences students' development to higher levels (Zeidler, Sadler, Applebaum, & Callhan, 2009). In the light of the present study, it can be suggested that the scientific reasoning skills of future scientists should be improved earlier in their school years. To that end, teachers should give students somethings to think and reason on.

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