ISSN 1648-3898

AN INVESTIGATION OF ELEMENTARY STUDENTS' SCIENTIFIC LITERACY LEVELS

Yasemin Özdem
Pınar Çavaş
Bülent Çavaş
Jale Çakıroğlu, Hamide Ertepınar

Abstract. *Scientific literacy has become the major goal of science education in many countries as well as Turkey. In line with this goal, the purpose of this study is to investigate the scientific literacy level of elementary students in Turkey. In this study, the scientific literacy level of students is investigated through "Scientific Literacy Test" adapted by the researchers. The test was administered to 946 elementary students enrolled in 6th, 7th and 8th grades in nine cities during the academic year of 2008-2009. The results of the study showed that 8th grade students significantly differ in their scientific literacy level compared to 6th and 7th grade students. However, eight graders have also some difficulties on some items related to the nature of science.*

Key words: *scientific literacy, elementary, science education.*

Yasemin Özdem
Gaziosmanpasa University, Tokat, Turkey
Pınar Çavaş
Ege University, Izmir, Turkey
Bülent Çavaş
Dokuz Eylul University, Izmir, Turkey
Jale Çakıroğlu, Hamide Ertepınar
Middle East Technical University, Ankara, Turkey

Introduction

In the 21st century, people need to follow and keep up with the rapid developments in science and technology. It is very important that information societies use these developments for the benefit of their future. In a rapidly changing world, at the very top of the list of educational goals, there is the need to educate young people in order them to know and be able to use new scientific and technological tools. Even though scientific literacy has been claimed as an important learning outcome for science education for years, research studies have shown that most of the people in developing or developed countries do not have adequate knowledge and skills related to science and technology (ETS 1988, AAAS 1989, Miller 1989, Halloun 1993, Shamos 1995, Eisenhart et al. 1996, Ogawa 1998, cited in BouJaoude, 2002). In many countries like Turkey, scientific literacy is reflected in the vision of new science curriculum as: "all students, regardless of individual and cultural differences, should develop scientific and technological literacy" (MoNE, 2006, p. 5). The objective of science curriculum is to promote scientific literacy, the scope of which includes understanding of the basic science concepts, utilizing science process skills, making meaningful connections of science, technology and society, developing values and attitude toward science and knowing the nature of science. Meanwhile, students need to improve some skills related to inquiry, critical thinking, problem-solving and decision making (National Academy of Sciences, 1998; Laugsch, 2000; Baram-Tsabari & Yarden, 2005; MoNE, 2006). The increasing demand in these skills especially becomes apparent in the elementary grades. In the studies related to scientific literacy, it is stated that elementary students experience a distinctive decrease in their attitudes and interest in science (Gräber, 1998, Osborne, 2003), and it is emphasized that these students need to be educated as scientifically literate in order to adapt to a new millennium dominated by science and technology (Holbrook & Rannikmae, 2007). On the other hand, studies related to scientific literacy mainly focus on higher levels of education rather than the elementary grades (Mbajiorgu & Ali, 2003; Chin, 2005; Nwagbo, 2006).

Although recently the concept of scientific literacy appears to be the main goal of science education curricula in many countries, there is no consensus on its meaning and content. To define the scientific literacy, many science educators as well as organizations such as National Research Council (NRC, 1996) and American Association for the Advancement of Science (AAAS), draw frameworks, and tried to describe the characteristics of a scientifically literate individuals. NRC (1996) defined scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p.22). AAAS (1991) stated in Project 2061 documents that science literacy broadly covers the connections among ideas in the natural and social sciences, mathematics, and technology. Pella, O'Hearn and Gale (1966) in their studies searched for almost hundreds of publications in order to describe characteristics of scientifically literate individual and as a result they stated that an individual who is scientifically literate should have an understanding in "... (a) basic concepts of science, (b) nature of science, (c) ethics that control the scientist in his [sic] work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities, and, (f) differences between science and technology." (p. 206).

Collette and Chiappetta (1989) claimed that scientific literate person understands the nature of science and how science, technology and society affect each other, and to develop a positive attitude towards science and technology. Miller (1983) defined scientific literacy as consisting of three related dimensions: "(a) an understanding of the norms and methods of science (i.e. the nature of science); (b) an understanding of key scientific terms and concepts (i.e., science content knowledge; and (c) an awareness and understanding of the impact of science and technology on society".

Science literacy is a well-known, yet controversial term. Dimensions suggested for science literacy cover: understanding (a) the nature of science and scientific knowledge; (b) scientific concepts/ principles/ theories; (c) how science and technology work together and (d) appreciating and understanding the impact of science and technology on society; (e) scientific communication competencies and very importantly, (f) applying scientific knowledge and reasoning skills to daily life (Miller, 1983; Shwartz et al., 2005). Shamos (1995) challenged the attainment of scientific literacy, if including areas such as (b) and (c). He challenged the notion of their being universal 'key concepts' in a culturally diverse world. Also challenged is how far scientific literacy relates to a need for applications such as scientific understanding of how technology works, as opposed to having the ability to transfer scientific learning to situations for decision making in socio-scientific areas of concern (Holbrook & Rannikmae, 2007; Bolte, 2008).

In summary, scientific literacy covers a range of knowledge and skills including the understanding of the effect of science and technology on our daily life, the acquisition of positive attitudes towards the use of scientific knowledge, asking scientific questions, and making inferences based on evidences (OECD, 2003; MoNE, 2006). Therefore, it is widely accepted that to become an effective member of the society in a rapidly changing world, one should have an adequate level of scientific literacy. Hence, the goal of science education curricula should be directly to educate individuals to become scientifically literate (Kolsto, 2000; Holbrook & Rannikmae, 2007).

Organization for Economic Co-operation and Development (OECD) grounded its scientific literacy definition on the skills such as the use of scientific knowledge, the statement of problems and offering evidence-based solutions for them, by means of these solutions understanding the environment and effects on environment, and making rational decisions (OECD, 1999). Sutman (1996) expressed that scientific literacy should not be limited to a dimension of science or scientific method, rather it should be understood with the skills such as understanding of scientific knowledge, developing one's own

ISSN 1648–3898

scientific point of view and methods, and sharing the knowledge gathered through scientific ways.

Scientific literacy is defined in a larger scope as science and technology literacy in the Elementary Science and Technology curriculum in Turkey (MoNE, 2006). In the present study however, scientific literacy will be defined in a narrow scope since science and technology literacy covers attitudes and values related to technology, which are out of the boundaries of this research. Technology literacy can be another area of study when the goals of this research are considered. In this sense, scientific literacy, as a general definition, should be thought as the combination of both insights related to science and scientific knowledge, as well as skills such as inquiry, critical thinking, problem solving and decision making. This definition requires a scientifically literate person to be able to understand science, the nature of scientific knowledge and the relationship of science with society and environment, to know basic scientific concepts, laws, theories and principles, and to use science process skills.

One of the world-wide known research in the area of scientific literacy is PISA (Programme for International Student Assessment) conducted by OECD. PISA is a triennial survey of the knowledge and skills of 15-year-olds in the domains of reading, mathematical and scientific literacy. The major focus of PISA 2006 assessment was science but the assessment also included reading and mathematics and collected data on student, family and institutional factors that could help to explain differences in performance. Students' background information and additional supporting information such as institutional factors was also collected via questionnaires. There were 400000 students from fifty-six countries participated in the assessment in 2006. In the part of scientific literacy in PISA 2006, Finland had a score of 563 and placed at the top of the list among other countries. In contrast, Turkey scored 424 and ranked 44 among 57 countries. When OECD countries are taken into account, only 1.3 % of the students participated in the assessment reached the 6th level, which is the top level that can be reached. In this level, students are able to define, explain and use scientific knowledge consistently in complex life situations. Finland and New Zealand ranked 3.9 %, which is three times the OECD average. In a level down, that is 5th level, students have an average of 9 %. For the 4th level, the average is 29.3 percent; for the 3rd level, it is 56.7 percent; for the 2nd level, it is 80.08 percent, and for the 1st level, it is 94.08 percent. Turkish students' ability levels and related percentages are given in Figure 1.

Figure 1. Turkish students' scientific ability levels and percentages in PISA 2006.

(Source: PISA 2006: Science Competencies for Tomorrow's World. *http://www.pisa.oecd.org/dataoecd/15/13/39725224.pdf*).

Figure 1 shows Turkish students' scientific ability levels and percentages in PISA 2006. According to the Figure 1, 12.9 % of Turkish students are below the first level, 33.7 % of Turkish students have such a limited scientific knowledge that it can only be applied to a few, familiar situations. They can present scientific explanations that are obvious and follow explicitly from given evidence. 31.3 % of Turkish students have adequate scientific knowledge to provide possible explanations in familiar context or draw conclusion based on simple investigations. They are capable of direct reasoning and making literal interpretations of the results of scientific inquiry or technological problem solving. Only 0.9 % of Turkish students can consistently identify, explain and apply scientific knowledge and knowledge about science in a variety of complex life situations. There is no Turkish student at the level 6 and show the abilities of this level.

Purpose of the Study

The purpose of this research is to examine the scientific literacy levels of students, who are enrolled in the upper elementary grades (6th, 7th and 8th grades). The research questions which direct this research are:

1. What is the level of scientific literacy for the students enrolled in 6th, 7th and 8th grades?
2. Is there any significant difference in students' scientific literacy scores regarding grades?
3. Is there any significant difference in students' science concept knowledge and nature of science scores regarding grades?

Methodology of Research

In the methodology section, we will describe the research design of our study, the sampling procedure of the participants, and the data collection and analysis procedure.

Research Design

To reveal the profile of populations in terms of their scientific literacy, researchers usually use quantitative approaches. For example, Durant, Evans, and Thomas (1989) developed and used a 23-item questionnaire to measure public understanding of science and the scientific process. They administered the questionnaire to the public and obtained low scores ($\bar{x}$ = 11.44, sd = 4.15, full score = 23) for the dimension of scientific knowledge. In the dimension of scientific process, the scores were even worse ($\bar{x}$ = 3.76, sd = 0.61, full score =9). The results showed that as little as 5% of US citizens were scientifically literate. The researchers carried out a similar investigation with the people in the United Kingdom by the same survey, which indicated that the scientific literacy level of British people was also low. Chin (2005) investigated if the first-year pre-service teachers in colleges in Taiwan have a satisfactory level of scientific literacy. In the study, Chinese translation of the Test of Basic Scientific Literacy (TBSL) were administered to elementary education majors (n = 141) and science education majors (n= 138) from four teachers' colleges. The results revealed that, in general, the basic scientific literacy of first-year pre-service teachers in Taiwan was at a satisfactory level. In the current study, a similar quantitative approach was used in order to investigate elementary students' scientific literacy in Turkey. The Turkish adaptation of the Test of Basic Scientific Literacy was used as an instrument to collect data.

Sampling Procedure

The data for the current study were obtained from 946 students ($n_{6th\ grade}$= 330, $n_{7th\ grade}$= 321 and $n_{8th\ grade}$=295) who were enrolled in upper elementary grades in the academic year of 2008-2009. Age range of students is from 12 years old to 15 years old. The cities where the data were collected from and the number of students participated in this study are given at Table 1.

ISSN 1648–3898

Table 1. The cities where the data collected and the number of students participated.

The city where the school is located	Sample of the study		
	6th grade	7th grade	8th grade
Bursa	14	23	13
Eskişehir	50	50	50
Muğla	22	33	30
Kocaeli	29	57	56
Denizli	20	31	36
Adana	40	31	0
Ordu	42	26	33
İstanbul	72	51	77
Ankara	30	30	0
Total	319	332	295

Data Collection Procedure

For the purpose of the study, the data were collected through the Test of Basic Scientific Literacy questionnaire, developed by Laugksch and Spargo (1996). The questionnaire was adapted from English to Turkish by the researchers.

In order to identify the level of scientific literacy, Laugksch and Spargo (1996) developed the Test of Basic Scientific Literacy (TBOT) by using the definition made by SFAA (Science for All Americans) and applying the three dimensional model suggested by Miller. TBOT is composed of three sub-scales: The nature of science, scientific concept knowledge and the effect of science and technology on society. Scientific concept knowledge sub-scale is also composed of three sub-categories, which are physical settings, human organism, and living environment. The test includes 110 items, which are statements related to the dimensions of scientific literacy.

The concept of scientific literacy is taken in a narrow scope in this research. For the purpose of this study, technological literacy is considered to be a different area of study. Therefore, items related to the technological literacy are excluded from this study.

The researchers adapted the test into Turkish and to elementary grades. First of all, the items were translated into Turkish. Secondly, to ensure the validity of the test, the researchers got the expert opinion about (1) the clarity of items in terms of understanding, and (2) the appropriateness of the items to the participants' age group. A group of science educators also examined the test and discussed its content validity for the appropriateness of the test for the Elementary Science and Technology Curriculum in Turkey. As a result, final version of the Scientific Literacy test (SLT) included a total of 41 items with two sub-scales named "The Nature of Science (NOS)" and "Scientific Concept Knowledge (SCK)" (Table 2).

Table 2. The sub-scales of the Scientific Literacy Test.

Sub-scale		The number of items
The Nature of Science (NOS)		22
Scientific Concept Knowledge (SCK)		19
	Total	**41**

For pilot testing, the final version of the SLT was applied to 129 elementary students enrolled in elementary schools in Ankara, the capital city of Turkey. In SLT, students can evaluate an item, which is a statement related to the sub-scales of the scientific literacy covered in this scale, by selecting one of three choices: "True", "False"; or "I Don't Know". The cronbach alpha coefficient was 0.74 for SLT.

Data Analysis Procedure

The data were analyzed using SPSS 11.5 statistical analysis package program. Descriptive and inferential statistics related to the scientific literacy test scores were presented in the results. As descriptive statistics, the scientific literacy levels for each grade were presented. As inferential statistics, one-way between groups ANOVA were conducted.

Results of Research

The participants' scientific literacy levels were identified by using SLT and for each grade level, the average scores for sub-scales of scientific literacy as well as the average scores which determine the scientific literacy levels were presented. In addition, one-way between groups ANOVA results were interpreted in order to find out whether there is a significant difference in scientific literacy levels for 6th, 7th and 8th grades.

Results Related to the Scientific Literacy Levels of the Participants

In this section, the results related to the scientific literacy levels of participants were presented descriptively. The maximum scores obtained from SLT, NOS and SCK are 41, 22 and 19 respectively.

Additionally, participants' average scientific literacy level was found to be 20.57, which refers almost to the half of the total score. When the average scientific literacy scores across grades were considered, 6th graders had the average scientific literacy level of 20.32, 7th graders had the average scientific literacy level of 19.59 and 8th graders had the average scientific literacy level of 21.92. It can be concluded from the results that elementary graders have almost a moderate level of scientific literacy.

The average levels of elementary students in the SLT in terms of two sub-scales, which are the NOS and SCK, were given in Table 3.

Table 3. The average scores on scientific literacy in terms of sub-scales.

Sub-scale	Grade	N	$\overline{X}$	S
The Nature of Science	6	330	10.33	2.86
	7	321	10.13	2.96
	8	295	11.08	3.07
	Total	946	10.50	2.98
Scientific Concept Knowledge	6	330	9.99	3.13
	7	321	9.46	2.99
	8	295	10.83	3.37
	Total	946	10.07	3.21

In the SLT, there are 22 items related to the NOS sub-scale. According to Table 4, elementary students' average scores in this sub-scale ($\overline{x}$= 10.50) is 47.72 % of the maximum score, which can be taken from this sub-scale. In the SLT, there are 19 items related to the SCK sub-scale. According to Table 4, elementary students' average scores in this sub-scale ($\bar{x}$= 10.07) was 53% of the maximum score, which can be taken from this sub-scale. It can be concluded from these results that elementary students are more successful in SCK sub-scale than in the NOS sub-scale.

When the average scores for each grade were analyzed in the sub-scale of the Nature of Science, it can be seen that 6th graders ($\bar{x}$= 10.33) reached to 46.95 % of the maximum score, which can be taken from this sub-scale, whereas 7th graders ($\bar{x}$= 10.13) had 46.05 % of the max score, and 8th graders ($\bar{x}$= 11.08) had 50.36 % of the max score. The item analysis results for this sub-scale were given in Figure 2.

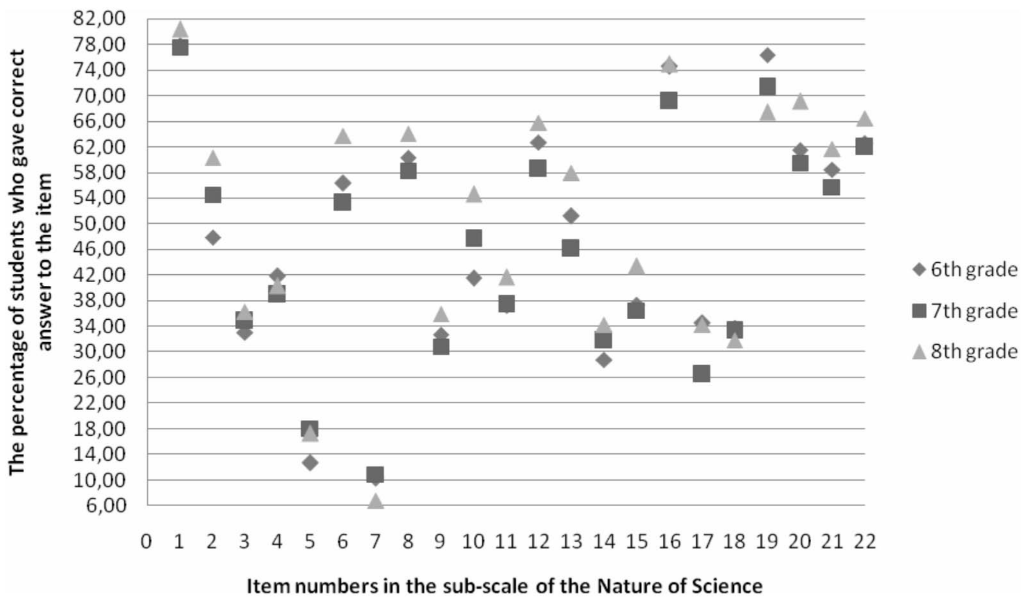

Figure 2. Item analysis for the sub-scale of the nature of science.

Item analysis revealed that in the sub-scale of Nature of Science, there were differences across grades in terms of correct answer percentage (Figure 2). According to the figure 2, 8th grade students had more correct answer percentage compared to 6th and 7th graders.

Item analysis put forth lower correct answer percentages in some items in the sub-scale of the NOS for 8th graders for consideration. As it can be seen in figure 2, 8th grade students had invalid conclusions in the items 7, 18 and 19 in the sub-scale of the Nature of Science. With reference to this, compared to 6th and 7th grade students, a large number of 8th grade students had some difficulties in the responding the following statements "Many aspects of our lives cannot be examined in a scientific way" (Item 7-True), "Even though many different people deal with science, scientific knowledge hardly ever reflects the values and viewpoints related to society" (Item 18- False), and "The dissemination of scientific knowledge is unimportant to the progress of science" (Item 19-False).

In SLT, there are 19 items related to SCK. According to Table 3, elementary students' average scores in this sub-scale ($\bar{x}$= 10.07) was 53 % of the maximum score, which can be taken from this sub-scale. When the average scores for each grades were analyzed in the sub-scale of the SCK, it can be seen that 6th graders ($\bar{x}$= 9.99) reached to 52.58 % of the maximum score, which can be taken from this sub-scale, whereas 7th graders ($\bar{x}$= 9.46) had 49.79 % of the max score, and 8th graders ($\bar{x}$= 10.83) had 57 % of the max score. The item analysis results for this sub-scale were given in Figure 3.

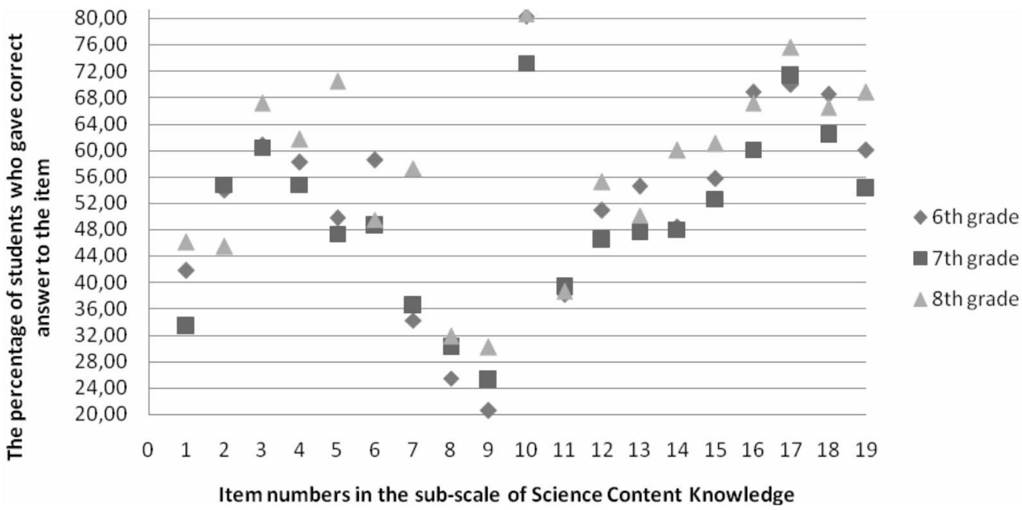

Figure 3. Item analysis for the sub-scale of science content knowledge.

Item analysis revealed that in the sub-scale of SCK, there were differences across grades in terms of correct answer percentage (Figure 3). Similar to the NOS sub-scale, in the SCK sub-scale, 8th grade students had more correct answer percentage compared to 6th and 7th graders.

Item analysis put forth lower correct answer percentages in some items in the sub-scale of the SCK for 8th grades for consideration. As it can be seen in figure 3, 8th grade students had invalid conclusions in the item 2 in the sub-scale of the SCK. With reference to this, compared to 6th and 7th grade, a large number of 8th grade students have a difficulty in the answering the following statement: "*The earth's axis is tilted, i.e. slanted.* This tilt produces seasonal changes in the earth's climate" (Item 2- True).

A one-way between groups analysis of variance was conducted to explore the impact of grade levels on the elementary students' scientific literacy levels, measured by SLT. The results were presented in Table 4.

Table 4. The impact of grade levels on the elementary students' scientific literacy levels.

Variable	Categories		N	X			S
Grade Level	6th grade	(1)	330	20.32			5.14
	7th grade	(2)	321	19.59			5.27
	8th grade	(3)	295	21.91			5.73
	The source of Variance	Sum of Squares	df	Mean Square	F	p	Sig.
	Between Groups	864.07	2	432.04	14.93	.000	3-1 3-2
	Within Groups	27281.54	943	28.93			
	Total	28145.61	945				

Subjects were divided into three groups according to their grade levels (Group 1: 6th grade; Group 2: 7th grade; Group 3: 8th grade). There was a statistically significant difference at the p<.05 level in Scientific Literacy scores for the three grade levels [F (2, 943) = 14, 93, p<.05]. Despite reaching statistical significance, the actual difference in mean scores between groups was quite small. The effect size was 0.03, which is calculated using eta squared. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Group 1 ($\bar{x}$= 20.32, sd= 5.14) was significantly different from Group 3 ($\bar{x}$= 21.92,

ISSN 1648–3898

sd=5.74). Moreover, the mean score for Group 2 ($\bar{x}$=19.59, sd= 5.27) was also significantly different from Group 3 ($\bar{x}$= 21.92, sd=5.74). However, there is no significant difference between Group 1 ($\bar{x}$= 20.32, sd= 5.14) and Group 2 ($\bar{x}$=19.59, sd= 5.27).

The items in the SLT with correct, wrong and 'don't know' percentages were given in Appendix A.

Conclusions

Scientific literacy has been recognized as an important characteristic that every citizen in a modern society should possess. In this respect science education is critical for developing students' scientific literacy, which is turn in future scientifically literate citizens. Therefore, this study was aimed at exploring the scientific literacy levels of elementary students enrolled in 6th, 7th and 8th grades, and the results of this study showed that elementary students have a moderate level of scientific literacy. This result is promising when the results of PISA 2006 assessment, which indicated that only a few number of these students were found to be able to identify the scientific components of many complex life situations, is considered.

However, it is clear that science educators should put in more efforts to increase the students' moderate level scientific literacy. After realizing the importance of scientific literacy as a major goal of science education in the world, science educators in Turkey made some efforts to improve science curricula. It is stated in the Science and Technology curriculum in Turkey that regardless of the individual differences, the main goal of science education is to educate all students as scientifically literate. Obviously, this effort would be useful in this regard because the new Turkish science curriculum might help students develop a moderate level of scientific literacy.

When the grade levels were examined in terms of scientific literacy levels, the results of this study revealed that students already have an average level of scientific literacy as they started upper elementary (e.g. 6th grade). Although the level of scientific literacy is seen to be increasing at 7th grade, there is no statistically significant difference between 6th and 7th grades in terms of scientific literacy level. A significant difference in increasing scientific literacy is only seen at 8th grade. In the light of these results, it can be concluded that although new Science and Technology curriculum makes a difference in scientific literacy for upper elementary students, it is not effective to raise the levels to more satisfactory. For that reason, it is necessary to explore ways to improve scientific literacy levels of students at each grade level. According to BouJaoude (2002) teaching, assessment, the quality of textbooks used, participating in extra-curricular scientific activities, and experiencing science in out-of-school contexts are important factors influencing the students' scientific literacy level.

It is clear in many studies that in order to promote scientific literacy, science teachers need to be well trained in their fields, have a firm understanding of the nature of science and should follow scientific and technological developments that affect society. Science teachers must engage students in the science revolution by relating it to their lives (Pearson, 1990). Millar (2007) also reported that scientific literacy based course is more popular when compared previous science courses and it stimulates greater interest and engagement with science.

Despite a number of different viewpoints in the description of scientific literacy in the literature, in this study, scientific literacy is considered to include the understanding of the NOS and SCK. The results of the study showed that students have a moderate level of scientific literacy in both sub-scales, and there is no significant difference in terms of neither NOS nor SCK. However, this study reported that students have relatively lower scores in NOS sub-scale than in SCK sub-scale. The lowest score was for NOS, probably due to the fact that it is given less emphasis in the science curriculum in Turkey. Most of the studies related to the nature of science indicated a similar result, that is students do not have an adequate level of understanding in the NOS (Doğan, & Abd-El-Khalick, 2008; Doğan Bora, Arslan, & Çakıroğlu, 2006; Ebenezer, & Zoller, 1993; Moss, & Robb, 2001; Kang, Scharmann, &Noh, 2005). It is, therefore, reasonable to suggest that the domains of the nature of science require particular emphasis in science education program. Although students had relatively high scores from scientific concepts knowledge sub-scale than NOS sub-scale, it was found that they still had some difficulties in understanding of certain scientific concepts. Similarly, previous studies have consistently indicated that elementary students have misconceptions in certain scientific topics. Being scientifically literate requires one to understand the NOS as well as basic scientific terms and concepts. Nevertheless, it would be worthwhile to investigate the scientific literacy including science process skills, science-technology-society interrelationships, values and ethics inherent in science. Additionally, it is recommended to apply the scales within a larger sample.

This study depends on quantitative data in order to examine the scientific literacy levels of elementary students. In the future, conducting qualitative studies provides more comprehensive information about students' scientific literacy level. Further studies are also needed to investigate effect of different variables on students' scientific literacy levels. Furthermore, it is clear that there is a need to scientifically literate teachers in order to develop satisfactory level of scientific literacy among students. For this reason, there should be an integration of activities aimed at improving scientific literacy in teacher education programs.

If scientific literacy will be an effective objective in elementary science curricula, the following recommendations are valuable to keep in mind:

1. Scientific literacy should be examined with a wider perspective including other sub-scales stated in the curriculum as well as the ones existing in this study. In this context, it should be aimed that students understand the NOS and scientific process, and internalize SCK through active participation.
2. There should be an effective assessment strategy (1) to determine whether the curriculum achieves the stated scientific literacy objectives including not only SCK but also the understanding of the NOS, science process skills, science-technology-society and environment relationships, and attitudes-values inherent in science, (2) to provide feedback for revisions in the curriculum to achieve scientific literacy.

Acknowledgement

This study was sponsored by the Office of Scientific Research Projects Coordination at Middle East Technical University (BAP-2008-05-06-04). The researchers are also thankful to the school directors and teachers involved in this study for their incredible help and support.

References

AAAS. (1990). *Science For All Americans*. Oxford University Press, New York.

Baram-Tsabari, A., & Yarden, A. (2005). Text genre as a factor in the formation of scientific literacy. *Journal of Research in Science Teaching,* 42, 403-428.

BouJaoude, S. (2002). Balance of scientific literacy themes in science curricula: The case of Lebanon. *International Journal of Science Education,* 24(2), 139-156.

Bolte, C. (2008). A conceptual framework for the enhancement of popularity and relevance of science education for scientific literacy, based on stakeholders' views by means of a curricular delphi study in chemistry. *Science Education International,* 19(3), 331-350.

Chin, C. (2005). First-year pre-service in Taiwan- Do they enter the teacher program with satisfactory scientific literacy and attitudes toward science? *International Journal of Science Education,* 27(13), 1549-1570.

Collette, A. T., & Chiappetta, E. L. (1989). *Science instruction in the middle and secondary schools* (2nd ed). Columbus, Ohio: Merrill Publishing Company.

Doğan Bora, N., Arslan, O., & Çakıroğlu, J. (2006). Lise öğrencilerinin bilim ve bilim insani hakkındaki görüşleri. *Hacettepe Eğitim Fakültesi Dergisi,* 31, 32-44.

Dogan, N & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching,* 45(10), 1083-1112.

Durant, J. R., Evans, G. A., & Thomas, G. P. (1989). The public understanding of science. *Nature,* 340(6), 11-14.

Ebenezer, J. V., & Zoller, U. (1993). Grade 10 students' perceptions of and attitudes toward science teaching and school science. *Journal of Research in Science Teaching,* 30(2), 175-186.

Gräber, W. (1998). Schooling for life-long attention to chemistry issues: The role of interest and achievement. In L. Hoffmann, A. Krapp, K. A. Rennin-ger & J. Baumert (Eds.), Seeon-conference on interest and gender. Seeon: IPN Kiel.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *Inter-*

ISSN 1648–3898

national Journal of Science Education, 29 (11), 1347-1362.

Kang, S., Scharmann, L.C., & Noh, T. (2005). Examining students' views on the nature of science: Results from Korean 6th, 8th, and l0th graders. *Science Education,* 89, 314-315.

Kolstø, S. D. (2000). Consensus Projects: Teaching science for citizenship. *International Journal of Science Education, 22,*645-664.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education,* 84, 71-94.

Laugksch, R.C., & Spargo, P.E. (1996). Construction of a paper-and-pencil test of basic scientific literacy goals recommended by the American Association for the Advancement of Science. *Public Understanding of Science,* 5, 331-359.

Layton, D., Davey, A., & Jenkins, E. (1986). Science for specific social purposes (SSSP): Perspectives on adult scientific literacy. *Studies in Science Education*, 13, 27-52.

Layton, D., Jenkins, E., Macgill, S., & Davey, A. (1993). *Inarticulate science? Nafferton*, UK: Studies in Science Education.

Lee, Y. (2003). *An investigation of Taiwanese graduate students' level of civic scientific literacy*. Unpublished doctoral thesis, The University of Texas at Austin.

Mbajiorgu, N. M. & Ali, A. (2003). Relationship between STS approach, scientific literacy, and achievement in biology. *Science Education,* 87*,* 31-39.

MoNE (2006). *İlköğretim Fen ve Teknoloji Dersi (6, 7 ve 8. sınıflar) Öğretim Programı*. MEB Yayınları, Ankara.

Millar, R. (2007) Scientific literacy: Can the school science curriculum deliver? M. Claessens (ed.), *Communicating European Research*, 145-150, Springer Netherlands.

Miller, J.D. (1983). American people and science policy. In *The Role of Public Attitudes in the Policy Process*. New York: Pergamon Press.

Moss, D.M., Abrams, E.D., & Robb, J. (2001). Examining student conceptions of the nature of science. *International Journal of Science Education,* 23, 771-790.

National Academy of Sciences. (1998). *Every child a scientist: Achieving scientific literacy for all. How to use the "National Science Education Standards" to improve your child's school program.* Eric Database Accession Number: ED425929.

National Research Council (NRC). (1996). *National science education standards*. Alexandria, VA: National Academic Pres.

Nwagbo, C. (2006). Effects of two teaching methods on the achievement in and attitude to biology of students of different levels of scientific literacy. *International Journal of Educational Research,* 45*,* 216-229.

Organization for Economic Cooperation and Development. (2003). *The PISA 2003 assessment framework-mathematics, reading, science and problem solving knowledge and skills.* Retrieved December, 2007, from http://www.pisa.oecd.org/dataoecd/46/14/33694881.pdf

Osborne, J. (2003). Attitudes towards science: a review of the literature and its implications, *International Journal of Science Education*, 25, 1049–1079.

Pearson, E. (1990) Scientific literacy: What is the role of the science teacher? *Journal of Negro Education*, 59(3) 316-319

Pella, M. O., O'Hearn, G. T. & Gale, C. W. (1966). Scientific literacy- Its referents. *The Science Teacher,* 33(5), 4.

Roth, W. M. & Lee, S. (2004). Science education as/for participation in the community. *Science Education,* 88, 263-291.

Shamos, M. (1995). *The myth of scientific literacy*. New Brunswick, NJ: Rutgers University.

Shwartz, Y. Ben-Zvi, R. & Hofstein, A. (2005). The importance of involving high-school chemistry teachers in the process of defining the operational meaning of 'chemical literacy', *International Journal of Science Education*, 27(3), 323-344.

Sutman, F.X. (1996). Scientific lLiteracy: A functional definition. *Journal of Research in Science Teaching*, 33, 459-461.

Ziman, J. (1991). Public understanding of science. *Science, Technology, & Human Values*, 16(1), 99-105.

Appendix A. Item analysis with regard to correct, wrong and don't know answers.

Sub-scale	*	**		Percentages		
		#	Item	C	W	DNK
SCK	1	1	The earth is as old as the universe.	40.27	32.14	27.59
SCK	2	2	The earth's axis is tilted, i.e. slanted. This tilt produces seasonal changes in the earth's climate.	51.59	27.38	21.04
SCK	3	3	Human activities have hardly changed the earth's land surface, oceans, and atmosphere.	62.68	17.86	19.45
NOS	1	4	Scientists share certain beliefs and attitudes about the work they do	78.54	10.57	10.89
NOS	2	5	Science takes for granted that the things and events in the universe do not occur in consistent patterns.	54.02	19.66	26.32
NOS	3	6	Science assumes that the basic rules about how the universe operates are the same throughout the universe.	34.67	29.92	35.41
NOS	4	7	There are many aspects of our lives that cannot be usefully examined in a scientific way.	40.38	46.62	13.00
NOS	5	8	There are fixed steps that scientists always follow to lead them without fail to scientific knowledge.	15.96	64.27	19.77
NOS	6	9	Sooner or later, the validity (i.e. truth) of scientific claims is settled by referring to observations of phenomena.	57.61	20.40	21.99
NOS	7	10	Scientists disagree about the principles of logical reasoning that connect evidence with conclusions.	9.41	72.20	18.39
NOS	8	11	The process of putting forward and testing hypotheses (i.e. provisional explanations) is not one of the chief activities of scientists.	60.78	16.07	23.15
NOS	9	12	Scientists try to make sense of phenomena by inventing explanations for them. These explanations rarely use currently accepted scientific principles.	33.09	39.32	27.59

* The number of the item in the subscale in which it is located.
** The number of the item in the test.

Appendix A. Item analysis with regard to correct, wrong and don't know answers (cont'd).

Sub-scale	*	**		Percentages		
		#	Item	C	W	DNK
NOS	10	13	Scientific theories should explain additional observations that were not used in developing the theories in the first place.	47.67	17.23	35.10
NOS	11	14	Scientific evidence can be biased (i.e. distorted) in the way that data are interpreted, recorded, reported or selected.	38.69	38.05	23.26
NOS	12	15	Scientists may, because of their background, personal beliefs and values, emphasize different interpretations of evidence.	62.26	20.82	16.91
NOS	13	16	Scientists try to identify possible bias in the work of other scientists.	51.59	27.70	20.72
NOS	14	17	In carrying out an investigation, no scientist must be made to feel that s/he should reach a particular result.	31.50	50.85	17.65
NOS	15	18	Even though science is an activity carried out by many different people, science hardly ever reflects values and viewpoints related to society (e.g. views on women, political beliefs).	38.90	34.78	26.32
NOS	16	19	The dissemination of scientific knowledge is unimportant to the progress of science.	72.83	17.44	9.73
NOS	17	20	Scientific fields such as chemistry and biology have fixed boundaries or borders.	31.71	41.23	27.06
NOS	18	21	The bodies (e.g. the different government departments) which supply money for research influence the direction of science (i.e. which research to undertake).	32.98	29.60	37.42
NOS	19	22	Most of the scientists behave ethically and honestly while dealing with science	71.88	13.53	14.59
NOS	20	23	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harm that could result from scientific experiments.	63.21	13.64	23.15

* The number of the item in the subscale in which it is located.
** The number of the item in the test.

Appendix A. Item analysis with regard to correct, wrong and don't know answers (cont'd).

Sub-scale	*	**		Percentages		
		#	Item	C	W	DNK
NOS	21	24	Scientific ethics (i.e. system of morals) is concerned with, amongst other things, the possible harmful effects of applying the results of research.	58.56	14.80	26.64
NOS	22	25	Scientists can seldom bring final answers to matters of public debate (e.g. nuclear power or conservation of the environment).	63.53	17.76	18.71
SCK	4	26	Biologists classify living beings into groups and sub-groups. This classification is done without consideration of the body structure and behavior of living beings are.	58.14	21.99	19.87
SCK	5	27	Each gene is one or more specific part of the DNA molecule.	55.39	15.01	29.60
SCK	6	28	Chemical events in the cell is controlled from both inside and outside of the cell.	52.33	24.10	23.57
SCK	7	29	In an ecosystem every species, directly or indirectly, is dependent on other species in the system.	42.18	20.93	36.89
SCK	8	30	Only a part of life in the world maintains its presence by the transformation of energy from the sun.	29.07	50.74	20.19
SCK	9	31	Evolution is not an event, in which much simpler life structures are replaced with the top-level life structures.	25.16	38.58	36.26
SCK	10	32	Depending on temperature and pressure, all matters can exist in different states (for instance; solid, liquid, and gas).	78.01	11.84	10.15
SCK	11	33	Whenever energy in a form (e.g. heat) or a location decreases, the same amount of energy increases in another location or form.	38.69	27.27	34.04

* The number of the item in the subscale in which it is located.
** The number of the item in the test.

Appendix A. Item analysis with regard to correct, wrong and don't know answers (cont'd).

Sub-scale	*	**		Percentages		
		#	Item	C	W	DNK
SCK	12	34	Nothing in the universe - from atoms to living things to stars - is at rest, but is always moving relative to something else.	50.74	22.62	26.64
SCK	13	35	Every object in the universe applies gravitational force on other objects.	50.85	28.01	21.14
SCK	14	36	Despite the diversity of people in body structure and skin color, all people is the same species.	51.90	31.61	16.49
SCK	15	37	Infant mortality rate has nothing to do with health services, hygiene and medical care.	56.34	23.78	19.87
SCK	16	38	The systems of the human body have no separate and specific tasks.	65.33	19.98	14.69
SCK	17	39	Any new-born animal shows certain patterns of behaviour without having been taught such behaviour. For example; some animals suck their mother's breast for milk without being told.	72.20	11.95	15.86
SCK	18	40	The good health of individuals is independent of people's collective effort to take steps to keep their air, soil, and water safe.	65.75	21.25	13.00
SCK	19	41	Biological abnormalities cause some serious psychological disturbances.	60.78	10.25	28.96

* The number of the item in the subscale in which it is located.
** The number of the item in the test.

Received 17 November 2009; accepted 25 January 2010

Yasemin Özdem	Research Assistant, Middle East Technical University, Faculty of Education, Department of Elementary Education, Ankara/Turkey Phone: + 90 312 210 7507. E-mail: yozdem@metu.edu.tr Website: http://www.metu.edu.tr/
Pınar Çavaş	Research Assistant, Ege University, Faculty of Education, Department of Elementary Education, Bornova-Izmir/Turkey. Phone: + 90 232 388 4000. E-mail: pinar.huyuguzel@ege.edu.tr
Bülent Çavaş	Instructor, Dokuz Eylul University, Faculty of Education, Department of Science Education, Buca-Izmir/Turkey. Phone: +90 232 420 4882-1648. E-mail: bulent.cavas@deu.edu.tr Website: http://people.deu.edu.tr/bulent.cavas
Jale Çakıroğlu	Associate Professor, Middle East Technical University, Faculty of Education, Department of Elementary Education, Ankara/Turkey. Phone: + 90 312 210 4051. E-mail: jaleus@metu.edu.tr Website: http://www.metu.edu.tr/
Hamide Ertepınar	Professor & Head of Department, Middle East Technical University Faculty of Education, Department of Elementary Education, Ankara/ Turkey. Phone: + 90 312 210 4048. E-mail: hamide@metu.edu.tr Website: http://www.metu.edu.tr/