

A Comparative Study between Greek Pre-service Teachers and Primary School Students' Scientific Literacy Levels

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ABSTRACT

In recent decades, enhancing scientific literacy has been the ultimate goal of science education worldwide. This effort aims to develop the skills by individuals to cope with the challenges of the modern world, which requires scientific knowledge and thinking. This research study aimed to investigate and compare the scientific literacy level of Greek pre-service teachers and primary school students. The total number of participants was 787, of which 362 were pre-service teachers and 425 primary school students. Scientific literacy was assessed with the selected response measure of demonstrated scientific literacy (SLA-D). According to descriptive analyses and statistical hypothesis tests, pre-service teachers' scientific literacy level was considered significantly higher than students, as was expected. However, the scientific literacy level of both pre-service teachers and students in the sample remained low. This work provides recommendations for actions that can help improve the scientific literacy level of both students and teachers so that schools become a source of scientifically literate future citizens.

KEY WORDS: Pre-service teachers; primary school; scientific literacy; students

INTRODUCTION

The rapid advances in science, technology, and engineering directly affect people's daily lives (Choi et al., 2011). Social and environmental issues and challenges, as well as natural disasters, have an increasing impact on people's lives for how they see the world, experience everyday phenomena around them, and interact with others (Tan and Kim, 2012). All these changes that modern society is undergoing make the need for scientifically literate people imperative (Deehan, 2017), as citizens should be able to make decisions about their daily lives based on scientific knowledge (Sharon and Baram-Tsabari, 2020).

Scientific Literacy

The term "science literacy" was initially coined in the 1950s by Hurd (1958) to express a set of goals for science education (Bybee, 2016). Despite the many attempts which have been made to define it (e.g., Pella et al., 1966; Shen, 1975; AAAS, 1993; DeBoer, 2000; Norris and Phillips, 2003; Roberts, 2007; Holbrook and Rannikmae, 2009; Choi et al., 2011; Bybee, 2016), there is no agreement on a common definition (Liu, 2013; Naganuma, 2017). Although the term varies from author to author, according to the literature, it falls on a spectrum between science as a body of knowledge and the utility of science in society (Holbrook and Rannikmae, 2009; Archer-Bradshaw, 2014).

Scientific literacy reflects a person's ability to understand scientific processes and apply meaningful scientific information to everyday life (Fives et al., 2014). A scientifically

literate person shows interest and can engage rationally in scientific matters, reflecting on the importance of science and technology personally and socially (OECD, 2016a). Scientifically, qualified individuals do not necessarily pursue careers as scientists; however, they can recognize that science, technology, and engineering are essential elements of modern culture that frame much of our thinking (OECD, 2017; Stylos et al., 2023).

The Role of Education in the Enhance of Scientific Literacy

Studies have shown that continuing education is the most important factor affecting scientific literacy (Laugksch and Spargo, 1996; Archer-Bradshaw, 2014). Developing scientific literacy is a crucial goal of science education as it develops skills to understand the use of science in everyday life (Dragoş and Mih, 2015).

In modern knowledge-based societies, there is a need for a comprehensive science education that begins in the early years (Vieira and Tenreiro-Vieira, 2016). Therefore, it is considered necessary to cultivate scientific literacy from the very 1st years of compulsory education (Kähler et al., 2020; Fragkiadaki et al., 2022). Therefore, the role of the teacher becomes decisive in teaching Science in the early years (Siry, 2013; Fragkiadaki et al., 2022). An essential prerequisite is that primary education teachers have knowledge and skills that will enable them to actively cultivate students' scientific literacy (Sargioti and Embalotis, 2020). This will create a context where students and teachers can understand and explore aspects of science together (Fragkiadaki et al., 2022).

Conceptualization of Scientific Literacy

Fives et al. (2014) conducted a systematic literature review examining how scientific literacy is defined. They also looked at critical skills considered necessary for science literacy. According to their review, the writings created a framework for conceptualizing scientific literacy. This framework includes six components that reflect their view of the nature of scientific literacy: the role of science, scientific thinking and practice, science and society, literacy in science media, mathematics in science, and motivation and beliefs about science. Based on this framework, they developed a scientific literacy assessment (SLA) measure. This measure aims to evaluate the understanding of science and not exclusively the knowledge of a scientific field.

Role of Science

The role of science reflects the functioning of science in terms of (a) the questions that can be answered through science, (b) the nature of scientific endeavors, and (c) scientific concepts used in scientific disciplines (Fives et al., 2014). Science education should prepare students to recognize when an everyday problem is translated into scientific terms to lead to answers (Feinstein et al., 2013).

Scientific thinking and practice

This component refers to the scientific procedures that must be applied to answer questions that can be answered through science (Fives et al., 2014). Scientific thinking is something people do, not something they have (Kuhn, 2010). Thus, it includes the ability to describe and explain natural phenomena, evaluate evidence, distinguish between evidence and theory, and recognize false theories and incorrect explanations (Zimmerman and Klahr, 2018).

Science and society

In the post-Covid-19 pandemic era, the development of scientific literacy is seen as vital to addressing global challenges (Valladares, 2021). Scientific literacy has as a fundamental condition the existence of scientific understandings and skills on the part of citizens for full participation in the decision-making process both at the individual and collective level (Liu, 2009, 2013). Individuals must understand science's role in social issues (Fives et al., 2014). Hence, it becomes clear that the interaction of science and society promotes a society's welfare, security, and economic development (Liu, 2009, 2013).

Science media literacy

Significant media technology developments challenge citizen interaction and engagement with science (Tseng, 2018). Although new media environments provide opportunities for increased public access to further information about science, the risk of access to misinformation and the spread of questionable scientific ideas is likely (National Academies of Sciences, Engineering, and Medicine, 2016). Scientific media literacy refers to the ability of individuals to evaluate, critically examine and apply their scientific thinking to reports in science

and scientific arguments described or depicted in the media (Fives et al., 2014). Public inadequacy and misinformation on scientific issues (e.g., vaccine safety and climate change) are familiar. However, the current state of political environments and fundamental changes in the dissemination of information by the media give the problem new urgency (Scheufele and Krause, 2019).

Mathematics in science

Mathematics in science can be considered a distinct component in scientific literacy (Fives et al., 2014) can be assessed separately from science literacy. Practical knowledge of mathematics (e.g., reading graphs and understanding percentages) is necessary to understand and interpret science in everyday life fully (Fives et al., 2014). Therefore, understanding mathematics and using it to communicate and evaluate scientific evidence is of central importance for a person in modern society since many everyday problems and situations faced by contemporary citizens require some mathematical knowledge (OECD, 2019).

Motivation and beliefs about science

Scientific knowledge is not the only factor influencing the scientific literacy level (Fives et al., 2014). Attitudes toward science are also integral to scientific literacy (OECD, 2016a). Attitudes toward science, as a construct of motivation and beliefs towards science, play an essential role in students' participation in scientific issues (Bybee and McCrae, 2011; OECD, 2016a; Osborne et al., 2003). The value of science (subjective task value), science self-efficacy and personal epistemology are motivations and beliefs that enhance students' engagement with science and contribute to the achievement of science literacy (Fives et al., 2014; Osborne et al., 2003). Therefore, according to Fives et al. (2014), a person who values the utility of science feels capable of participating in scientific activities and believes that knowledge in science is human-developed and changing, may be perceived as a scientifically literate person.

METHODOLOGY

The Present Study

This research aims to investigate and compare the level of scientific literacy among 6th-grade primary school students and pre-service primary school teachers. The study investigated the following research questions:

1. What are students' and pre-service teachers' scientific literacy levels?
2. What is the difference, if any, between a meaningful difference between the science literacy level of students and pre-service teachers?

Participants

The study sample was drawn from 6th-grade students (students aged 11–12) and pre-service teachers in Greece. A convenience sample was made and consisted of 787 people who were divided into two groups of interest. The first group

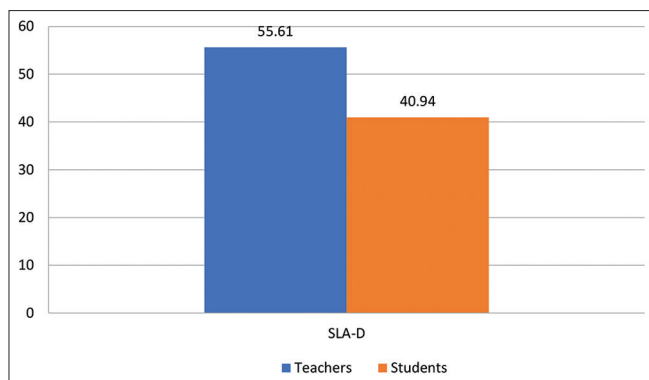


Figure 1: SLA-D mean score between groups

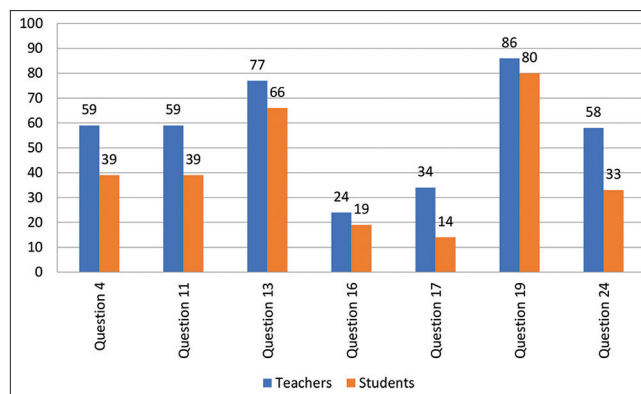


Figure 5: Mean score in "Science and society" component

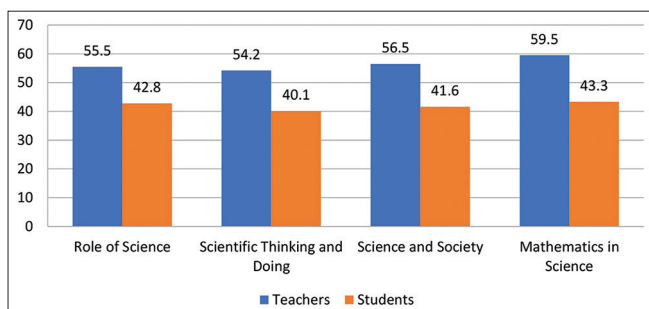


Figure 2: Mean score in scientific literacy components

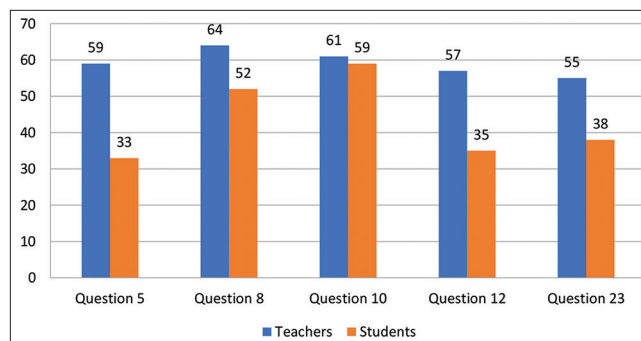


Figure 6: Mean score in "Mathematics in Science" component

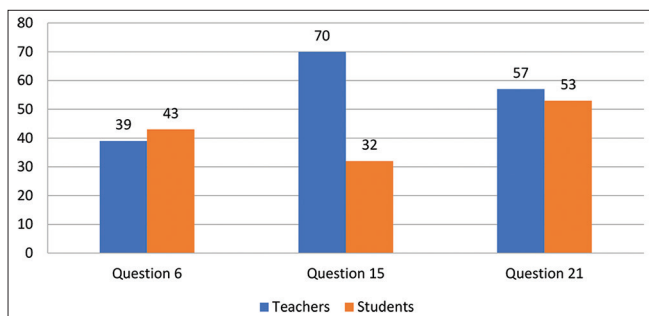


Figure 3: Mean score in "Role of Science" component

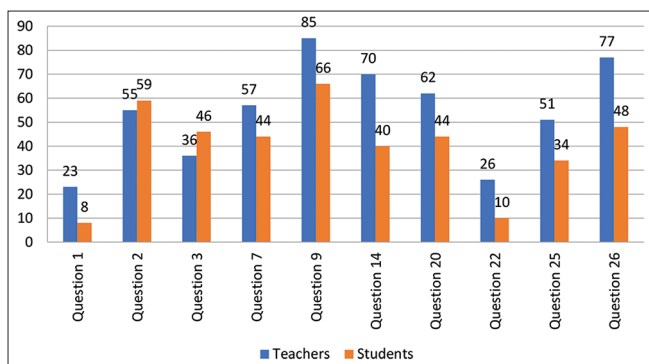


Figure 4: Mean score in "Scientific Thinking and Doing" component

comprised 425 6th-grade students from nineteen schools in urban, suburban, and rural areas across the Regional Unit of Ioannina, Northwestern Greece. The pre-service teachers'

group comprised 362 undergraduates in the Department of Primary Education, University of Ioannina, Northwestern Greece. All participants participated voluntarily and submitted parental and student assent forms.

Instrument

The instrument used for this study was SLA-D, see Appendix 1. The SLA-D is part of the SLA developed by Fives et al. (2014) to initially assess the scientific literacy of students aged 11–14 years. The SLA-D consists of 26-multiple-choice items that use everyday situations and examples to test scientific literacy by examining participants' understanding of the role of science, their scientific thinking and practice, the role of science in society, science media literacy, and mathematics in science (Fives et al., 2014). According to Fives et al. (2014), in the final conceptualization of science literacy, science and society and science media literacy were merged into one component.

The SLA was translated into Greek following the International Test Commission (ITC) guidelines for test adaptation (Hambleton, 2001) and suggestions from Beaton et al. (2000). Items of the original version were translated into Greek by two bilingual speakers. Subsequently, vocabulary adaptations were made after several discrepancies were found in the back translation. Moreover, each item of the scale was examined by a panel of researchers/experts familiar with the literature and research field to establish face validity and the questionnaire's content and cultural appropriateness. Finally, minor wording changes were made for age appropriateness.

Data Collection

Data collection started in October 2020 and finished in March of 2021. Due to the Covid-19 pandemic, the survey was conducted observing all the necessary protective measures imposed to contain the disease. The questionnaire was sent to the pre-service teachers by e-mail. Students completed the questionnaire in class. The questionnaires were completed without the presence of any of the authors of this research in the classroom due to special health conditions. However, instructions were given to the teachers about the questionnaire. The estimated time required to complete the questionnaire was 50–60 min.

Statistical Data Analysis

All statistical analyses were performed with the IBM SPSS 26.0 statistical package and Microsoft Office Excel spreadsheets.

Participants' responses were analyzed based on the four elements that together reflect the nature of science literacy: the role of science, scientific thinking and doing, science and society, and mathematics in science (Fives et al., 2014).

The internal consistency of the evaluation measure was examined. Regarding the SLA-D, responses were scored on a binary scale (incorrect-correct). To examine the reliability of the SLA-D, the Kuder-Richardson's coefficient was used (KR20) was equivalent to Cronbach's alpha (Fives et al., 2014). The KR20 measures the reliability of the test when items are coded as binary (Kuder & Richardson, 1937; Faremi, 2016).

In terms of reliability, the Kuder-Richardson coefficient suggests moderate reliability (0.65–0.68) but is acceptable for research of a cognitive nature (Chu et al., 2012; Glen, 2023; Stylos et al., 2021).

Finally, descriptive analyses and statistical hypothesis testing were performed to detect the differences in the SLA-D's mean scores among students and pre-service teachers. Specifically, in cases where the assumption of normality was not satisfied, non-parametric tests examined any potential differences in mean scores of the SLA-D (Field, 2018). Instead of independent t-tests, Mann–Whitney tests were performed (Koutsianou and Emvalotis, 2019). The assumption of normality was confirmed by histograms and boxplots in addition to statistical tests such as the Kolmogorov–Smirnov test and the Shapiro–Wilk test.

RESULTS

Descriptive Analyses and Hypothesis Tests

The average score of correct answers in the SLA-D

The pre-service teachers' mean score on the SLA-D was 55.61 (SD = 16.80) and the students' mean score was 40.97

(SD = 15.05) [Figure 1]. Mann–Whitney tests were conducted to examine if there were any statistically significant differences in scores according to the two groups. The results revealed that there is a statistically significant difference between pre-service teachers' and students' average scores on the SLA-D, $U = 113.763.500$, $z = 11.615$, $\rho = 0.000$, $r = 0.414$.

The average score of correct answers according to four components

The mean scores of the two groups for all components are shown in Table 1. The scores for all were classified as low [Figure 2]. Based on Table 1, pre-service teachers performed better than students in all categories. Mann–Whitney tests were performed to examine whether there were statistically significant differences in scores according to the two groups.

The results revealed a statistically significant difference between the mean scores of pre-service teachers and students in all components. In detail, the results are “Role of Science, $U = 94,314,500$, $z = 5,744$, $\rho = .000$, $r = .204$, “Scientific Thinking and Doing, $U = 106,728,500$, $z = 9,478$, $\rho = 0.000$, $r = 0.338$, “Science and Society $U = 107,205,500$, $z = 9,709$, $\rho = 0.000$, $r = 0.346$, and “Mathematics in Science $U = 103,306,500$, $z = 8,491$, $\rho = 0.000$, $r = 0.302$.

Role of Science

According to the “Role of Science” results [Figure 3], students achieved a higher score only in question 6, which refers to using scientific methods and instruments [Table 2]. Pre-service teachers scored higher on questions concerning identifying questions that can be answered through scientific inquiry. This result is similar to that of the Fausan and Pujiastuti (2017) survey.

Scientific Thinking and Doing

Both groups scored very low on questions 1 and 22 [Table 3]. These questions concerned the identification of study variables. The highest score that both groups scored was on question 9 [Table 3]. Thus, both groups can understand the process of concluding based on evidence [Figure 4].

Science and society

Two questions (16 and 17) with a meager score were observed in Science and Society [Figure 5 and Table 4]. Both groups could not recognize some scientific observation in an incident. In addition, the low score on question 17 showed that both groups need more skills to evaluate a scientific report. Furthermore, question 19 with the highest score from both groups was observed in the specific aspect of scientific literacy [Figure 5 and Table 4]. In question 19, participants were required to understand the role of science in political

Table 1: Differences in SLA-D components between two groups

Group	Role of science	Scientific thinking and doing	Science and society	Mathematics in science
Pre-Service Teachers	55.5	54.2	56.5	59.5
Students	42.8	40.1	41.6	43.3
Average	48.7	46.6	48.4	50.7

Table 2: Differences in “role of science” component

Item	Role of science					
	Teachers		Students		Included	
	Mean	SD	Mean	SD	Mean	SD
6	0.39	0.489	0.43	0.496	0.41	0.493
15	0.70	0.459	0.32	0.467	0.49	0.500
21	0.57	0.495	0.53	0.500	0.55	0.498

Table 3: Differences in “Scientific thinking and doing” component

Item	Scientific Thinking and Doing					
	Teachers		Students		Included	
	Mean	SD	Mean	SD	Mean	SD
1	0.23	0.424	0.08	0.275	0.15	0.360
2	0.55	0.498	0.59	0.492	0.57	0.495
3	0.36	0.481	0.46	0.499	0.42	0.493
7	0.57	0.495	0.44	0.498	0.50	0.500
9	0.85	0.359	0.66	0.474	0.75	0.435
14	0.70	0.458	0.40	0.490	0.54	0.499
20	0.62	0.487	0.44	0.497	0.52	0.500
22	0.26	0.438	0.10	0.305	0.17	0.379
25	0.51	0.501	0.34	0.475	0.42	0.494
26	0.77	0.423	0.48	0.500	0.61	0.487

Table 4: Differences in “Science and Society” component

Item	Science and Society					
	Teachers		Students		Included	
	Mean	SD	Mean	SD	Mean	SD
4	0.59	0.493	0.39	0.489	0.48	0.500
11	0.59	0.493	0.39	0.488	0.48	0.500
13	0.77	0.424	0.66	0.475	0.71	0.455
16	0.24	0.426	0.19	0.395	0.21	0.410
17	0.34	0.473	0.14	0.351	0.23	0.423
19	0.86	0.348	0.80	0.402	0.83	0.379
24	0.58	0.494	0.33	0.471	0.45	0.498

Table 5: Differences in “Mathematics in science” components

Item	Mathematics in science					
	Teachers		Students		Included	
	Mean	SD	Mean	SD	Mean	SD
5	0.59	0.492	0.33	0.472	0.45	0.498
8	0.64	0.480	0.52	0.500	0.58	0.495
10	0.61	0.488	0.59	0.493	0.60	0.491
12	0.57	0.495	0.35	0.477	0.45	0.498
23	0.55	0.498	0.38	0.485	0.45	0.498

decision-making (Diana et al., 2015; Fausan and Pujiastuti, 2017).

Mathematics in science

In this particular component, both groups achieved their highest score [Figure 6]. The teachers excelled in all categories. Noteworthy was the result in question 10, concerning the average number of a value. It seems that both groups understood the specific term at the same level. The predominance of teachers in all categories shows that they have a greater ability than students to use mathematics in science, for example, the ability to read scientific graphs [Table 5].

DISCUSSION

Through the literature review, a sample of studies related to evaluating scientific literacy in which the SLA-D instrument was used emerged. Six of the seven studies were conducted on middle or high school students (Fives et al., 2014; Diana et al., 2015; Rachmatullah et al., 2016; McKeown, 2017; Wilson et al., 2018; Rohana et al., 2020), while the other one was conducted on university students (Fausan and Pujiastuti, 2017). According to the literature review, no study was found on corresponding research that was done on pre-service teachers.

The results of this study showed that the average student’s score was very poor. Compared to most equivalent studies (Fives et al., 2014; Diana et al., 2015; Rachmatullah et al., 2016; McKeown, 2017; Wilson et al., 2018; Rohana et al., 2020) these students’ average score was significantly lower. Pre-service teachers’ average score was also low. Comparatively, the results align with similar research on university students of similar age (Fausan and Pujiastuti, 2017).

In the present study, pre-service teachers scored higher than students in all scientific literacy components. According to the results, the cognitive component, “Role of Science” reached a score that was categorized as low. Regarding the pre-service teachers, the result is similar to that obtained in other studies (Fausan and Pujiastuti, 2017). Students seem to lag behind other students who answered the same questionnaire (Rachmatullah et al., 2016; Rohana et al., 2020). The lowest score achieved was in the “Scientific Thinking and Doing” category. However, the score was similar (Fausan and Pujiastuti, 2017) or significantly better than that in other surveys for both students and pre-service teachers (Diana et al., 2015; Rachmatullah et al., 2016; Rohana et al., 2020). In the “Science and Society” aspect, pre-service teachers scored low. This finding contradicts the research results of other studies (Fausan and Pujiastuti, 2017). Corresponding are the results for the students. Finally, pre-service teachers scored highest in “Mathematics in Science”. The average score was higher compared with Fausan and Pujiastuti (2017) study. Students’ scores can be characterized as poor.

Several studies investigate the scientific literacy level of Greek students and pre-service teachers. According to the results of the PISA assessment for 2015, Greek students are ranked very low among the 35 OECD member countries. In the OECD survey conducted in 2018, the performance of Greek students is significantly lower than in 2015. The difference in the

performance of Greeks compared to the average performance is statistically significant (Sofianopoulou et al., 2017). In the present study, the student's performance is identical to that of the Greek students in PISA.

Similarly, in the PIAAC survey concerning adults, a large percentage of Greeks belong to the lowest level of competence (level 1 or below level 1) (OECD, 2016b). According to Kitsiou and Kotsis (2019), Greek pre-service teachers present, on average, a moderate to a low level in terms of scientific knowledge. The results of Sargioti and Emvalotis' (2020) research show that pre-service teachers have low levels of scientific literacy. In some cases, the teachers seem to need to catch up to the Greek 15-year-old students. Correspondingly are the results of the present research. However, students lag significantly behind teachers in all aspects of science literacy.

CONCLUSION

The present study results show that the pre-service teachers' scientific literacy level was categorized as low. Furthermore, students' scientific literacy ranged at a very low level. Between the two groups, pre-service teachers seemed to have significantly higher scientific literacy levels than students.

It is observed that pre-service teachers understood better than students when an everyday problem was translated into scientific terms. However, their level remained low. Both groups need to catch up in scientific thinking skills, such as identifying the variables of a study and generating questions about study design.

According to the results, the participants need help to apply scientific decisions to everyday issues. Both teachers and students may be more adept at memorizing scientific concepts than applying them. Instead, the participants can understand science's role in making political decisions. Finally, pre-teachers can know to some extent, the use and applications of mathematics in science.

Recommendations

Although knowledge of scientific content by individuals is important, it is not sufficient to achieve the goal of a scientifically literate society (Archer-Bradshaw, 2014). Importantly, individuals should approach scientific knowledge with a broader perspective, including its use to make informed decisions about socio-scientific issues that matter in everyday life (Fives et al., 2014). Therefore, teaching science through examples and situations that students encounter daily is recommended. Engaging students with such examples helps develop critical thinking skills and allows them to make connections between science and everyday life. But regardless of how science content knowledge affects students' level of scientific literacy, to be scientifically literate, students should also understand the nature of science and scientific inquiry (Bartels and Lederman, 2022). Hence, students need to be taught the basic aspects of science through the teaching of the Nature of Science (NOS). Furthermore, knowledge about

scientific inquiry is the student's understanding of how scientific knowledge is investigated. Finally, training and informing teachers about modern trends in science education (research-based teaching, STEM-based teaching) and their application in curricula is considered essential as it contributes to strengthening students' scientific literacy (Gomez and Suarez, 2020; Stylos et al., 2023).

Regarding pre-service teachers, their scientific literacy level is an important and critical point in the provision of high-quality and effective scientific education (Al Sultan et al., 2018). Therefore, activities aimed at improving scientific literacy should be integrated into teacher education programs to provide the necessary training so that teachers are adequately prepared to teach science (Özdem et al., 2010). To accomplish this, it is important that teacher preparation programs consider that pre-service teacher populations consist of students at various learning positions in high school. In addition, emphasis should be placed on teaching the Nature of Science and approaching science as a source of knowledge for decision-making on socio-scientific issues.

Finally, in the context of the development of scientific literacy through the curricula of both students and teachers, it would be important to have an evaluation to examine whether the curriculum achieves the stated objectives of scientific literacy and to provide feedback so that the respective curriculum to be revised.

ETHICAL STATEMENT

An official application was made to the schools' administration where the research was conducted for ethical permissions. For the research, student parents were also informed, and volunteering permission and participation permission were obtained. The confidentiality and anonymity of the data were ensured throughout the collection and evaluation.

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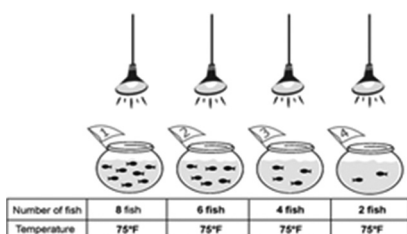
APPENDIX

Appendix 1: SLA-D

SCIENCE SURVEY

Directions: For each question, select one (1) answer and fill in corresponding circle on the separate bubble sheet.

1. ¹A student is interested in the behavior of fish. He has 4 fish bowls and 20 goldfish. He puts 8 fish in the first bowl, 6 fish in the second bowl, 4 fish in the third bowl, and 2 fish in the fourth bowl. He places each fish bowl under light, he keeps the temperature at 75° for all four bowls, and he observes the behavior of the fish.



What can the student find out from doing this experiment?

- A. If the number of fish in the fish bowl affects the behavior of fish
B. If the temperature of the fish bowl affects the behavior of fish
C. If the temperature of the fish bowl and the amount of light affect the behavior of fish
D. If the number of fish, the temperature, and the amount of light affect the behavior of fish
2. ²A science class is studying the effect of exercise on heart rate. Students perform jumping jacks and then measure their heart rate after all the jumps are completed. One group does jumping jacks for one minute. A second group does them for two minutes. A third group does not jump. How would you measure the result (outcome) of this experiment?
A. By counting the number of jumping jacks for one minute
B. By counting the number of heart beats in one minute
C. By counting the number of jumping jacks done by each group
D. By counting the difference in number of jumps between groups
3. On a walk home from school Carla closely examined her favorite tree. She made a few notes about the tree. Which of Carla's notes about the tree is an *interpretation*?
A. The bark is falling off. B. The leaves are brown. C. Birds are in the tree. D. The tree is sick.
4. A student finds a website created by the "No Homework Committee." He wants to find out the reasons for and against assigning homework to students. Is this a trustworthy source of information?
A. Yes. This group is against homework and knows all of the arguments.
B. Yes. Information on websites is always balanced and correct.
C. No. This group might give more attention to arguments against homework.
D. No. This group is probably not very good at arguing for or against homework.
5. In a town, 40% of the people have a certain illness. Fifty percent of the population is female. What percent of those who are ill are female?
A. 10% B. 20% C. 50% D. Cannot tell from the information given
6. Read the four questions below. Which question would be best answered by using scientific methods or instruments?
A. How much ice cream is sold each year? C. How was ice cream kept cold before freezers?
B. How did the first people make ice cream? D. How many calories are in a scoop of ice cream?
7. ³A group of students is making paper airplanes. They think that the kind of paper and the design of the airplane may affect how far each paper airplane flies. The students first test if the kind of paper affects how far the airplane flies. They make several airplanes out of different kinds of paper, using the same design. Why is it important that all the airplanes have the same design?
A. By using the same design, the students can learn about both the effect of the design and the effect of the paper.
B. By using the same design, the students can learn about the effect of the design.
C. If they do not use the same design, the students cannot learn about the effect of the paper.
D. It is **not** important for the airplanes to have the same design because the students are not testing the effect of the design.

(Contd...)

1. Project 2061 – Science Literacy for a Changing Future: American Association for the Advancement of Science
2. Dillashaw & Okey (1980) Test of Science Processes (TIPS)
3. Project 2061 – Science Literacy for a Changing Future: (AAAS)

Appendix 1: (Continued)

SCIENCE SURVEY

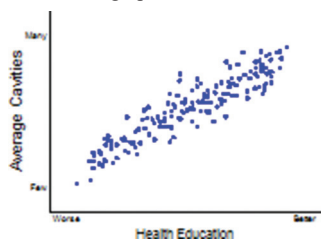
Directions: For each question, select one (1) answer and fill in corresponding circle on the separate bubble sheet.

8. Andrew, Lisa, and Min each worked on ten new math problems, every day for a week. The table below shows the number of correct answers for each student.

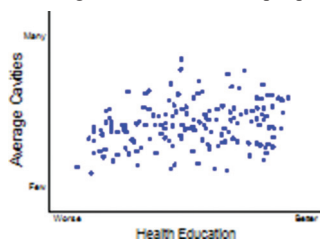
	Mon	Tue	Wed	Thu	Fri
Andrew	4	5	8	6	5
Lisa	3	8	6	5	8
Min	4	5	5	6	9

How many days did Lisa have the highest number correct?

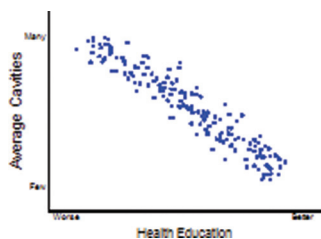
- A. 1
 B. 2
 C. 3
 D. 4
9. Who showed the most consistent improvement over time?
 A. Andrew B. Lisa C. Min D. Cannot tell from the information given
10. Which student had the highest average number correct over the 5 days?
 A. Andrew B. Lisa C. Min D. Cannot tell from the information given
11. Liberty Middle School changed its lunch schedule. The change was to have all students have recess BEFORE lunch, instead of after lunch. The principal said this change was made to help students eat healthier lunches. He said his decision was based on a scientific study. Which of the following study conclusions could justify this decision?
 A. Students who eat healthier lunches are more likely to play on sports teams.
 B. Students who play more at recess eat more fruits and vegetables at dinner.
 C. Students eat unhealthy lunches whether they have lunch first or recess first.
 D. Students who have recess before lunch choose less junk food at lunchtime.
12. Look at the graphs below. Which one shows that the average number of cavities per person is lower in countries with better health education?



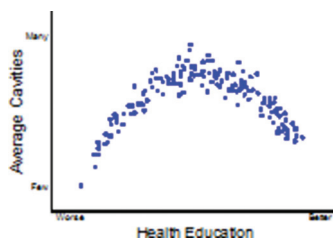
A. Graph A



C. Graph C



B. Graph B



D. Graph D

13. You receive an email that claims “People who sleep with books under their pillows get better grades through osmosis.” Osmosis is a scientific process. Some molecules pass through a semi-permeable layer while larger molecules are blocked. It is used to get pure water from salt water. It is used for other processes too. Based on this claim, should you sleep with your books to get better grades?
 A. Yes, if you use a semi-permeable pillow. C. No, because books under the pillow disrupt sleep.-
 B. Yes, because osmosis is a known scientific process. D. No, because osmosis is not related to grades.
14. A state records the number of car crashes each year. In 1 year, there were 1,056 car crashes on 4- or 6-lane highways. In the same year there were 589 car crashes on 2-lane highways. The governor concludes that driving on 4- or 6-lane highways is more dangerous than driving on 2-lane highways. What do you think about this conclusion?

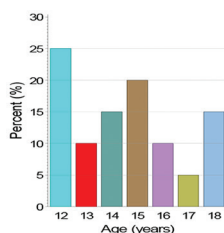
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Appendix 1: (Continued)

SCIENCE SURVEY

Directions: For each question, select one (1) answer and fill in corresponding circle on the separate bubble sheet.

- A. Correct. Highways that have 4 or 6 lanes are known to be more dangerous.
B. Incorrect. The number of accidents on 2 lane highways might be increasing.
C. Correct. States have more highways with 4 or 6 lanes than with 2 lanes.
D. Incorrect. He did not consider numbers of cars using each kind of highway.
15. Which of the following is **not** a hypothesis?
A. An educated guess B. The result of an experiment C. A proposed explanation D. An idea not proven
16. On February 2 in the U. S., many news reporters travel to local zoos to watch the behavior of a groundhog. Some people say that if the groundhog leaves his burrow and stays outside, spring will come sooner; if he runs back inside, there will be six more weeks of winter. This year the groundhog ran back inside.
What is the correct scientific observation about the occurrence?
A. The groundhog returned to his burrow. C. The groundhog was frightened by the reporters
B. There will be six more weeks of winter. D. Groundhogs have inborn weather reading abilities.
17. Arturo's parents want him to get better grades in school. His mother read a research study on the topic. After reading the study, she decided that from now on Arturo needed to be in bed by 9 PM. Which of these studies did Arturo's mother read?
A. When students go to bed by 9 pm they are less tired in school.
B. Students who get good grades are more alert when at school.
C. When students go to bed by 9 pm their school grades improve.
D. Students who go to bed earlier have more energy the next day.
18. What percent of the sample of people shown in the graph is older than 15 years?



19. More than 500 people in your town of 10,000 are sick with a mysterious illness. No one knows the cause, and the health officer is hoping that no one else gets sick. The governor is pressuring the town to take action. The media are covering the story every day. Parents are especially worried that their children might get sick. The town council decides to close the schools for 1 week.
Which of the following is a scientific reason behind the policy to close schools?
A. To reduce concern about the illness C. To reduce suffering from the illness
B. To reduce spreading of the illness D. To reduce expense from the illness
20. Sue wants to find out what growing conditions might affect the length of bean seedlings. She places a bean wrapped in moist tissue paper in each of ten identical test tubes. She puts five tubes in a rack in a sunny window. She puts the other five tubes in a dark refrigerator. Sue measures the lengths of the bean seedlings in each group of test tubes after 1 week.
Look at the variables listed below. Which variables was Sue testing to see how they affect the length of the bean seedlings?
A. Temperature and moisture C. Light and temperature
B. Moisture and length of test tube D. Light and amount of time
21. A country has a high number of decayed teeth (cavities) per person. Which question about tooth decay can only be answered with scientific experiments?
A. Do the men in this country have more tooth decay than women?
B. Would putting Vitamin D in the water supply affect tooth decay?
C. Has the number of decayed teeth increased in the past 10 years?
D. Is tooth decay more common in some parts of the country than others?
22. The principal of Riley Middle School wants to remove candy and soda (pop) vending machines. In their place, she wants to put in healthy food machines. She wants to know what her students will think of these changes. What would be the best way to get an accurate answer to this question?
A. Give a survey to all students who play on sports teams.
B. Give a survey to all students who attend a health fair.

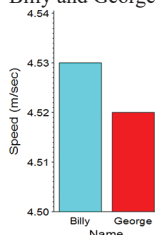
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Appendix 1: (Continued)

SCIENCE SURVEY

Directions: For each question, select one (1) answer and fill in corresponding circle on the separate bubble sheet.

- C. Give a survey to every 20th student on a list of all students.
D. Give a survey to all students who use the vending machines.
23. Billy and George raced their bikes five times. Billy made a graph of their average speeds.



- What can you reasonably conclude from the graph?
- A. George is a much worse bike rider than Billy.
B. Billy is a lot faster because his average speed is much higher than George's speed.
C. They are about the same because there is not much difference in their speed.
D. Billy won all five races.
24. A town council wants to protect cats from being hit by cars on town streets. They decide to adopt a policy of banning all pet cats from being outside. Which of the following is likely to be an unintended effect of this policy?
- A. A rise in mouse populations C. An increase in car accidents
B. A drop in pet cat populations D. A decrease in dog ownership
25. A TV weather report said, "New Jersey is heading for a severe water shortage!" Which type of evidence listed below would be the most important to support this claim?
- A. verage weekly rainfall
B. Average weekly temperature
C. Water levels at high tide
D. Number of cloudy days
26. A science journal publishes a study about effects of diet in rats. For 6 weeks, the scientists fed only dog food to 60 male rats. They fed normal rat food to another 60 male rats for the same 6 weeks. At the end of the 6 weeks, they counted the number of rats in each group that had developed dark spots. The results are in the table below.

	Rats That Developed Dark Spots	Rats That Did Not Develop Dark Spots	TOTAL
Fed dog food	42	18	60
Fed normal rat food	16	44	60

- Which conclusion is suggested by the results in this table?
- A. It is good to feed dog food to rats. C. Type of food is linked to dark spots in rats.
B. Rats with dark spots prefer dog food. D. Diet has nothing to do with rats getting dark spots.