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AN INVESTIGATION OF PRIMARY SCHOOL STUDENTS' SCIENTIFIC LITERACY

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Abstract:
Scientific literacy (SL) is critical for individuals to cope effectively with the everyday life situations of modern society. On this premise, this survey aims threefold: to validate the Greek version of the SL Assessment (SLA) tool, examine the SL of 425 Greek primary school students, and understand their attitudes and beliefs about science. Reliability and validity were investigated through statistical techniques, including exploratory factor analysis (EFA), confirmatory factor analysis (CFA), and the alpha-Cronbach coefficient. According to the statistical analyses, students have moderate to low SL levels. Variables such as gender and urban vs. rural setting appear to significantly impact the performance of the study's participants, and of particular interest are students' attitudes and beliefs about science. The research findings enhance concern over students' low SL level and the extent to which the school establishment responds to society's science needs and expectations.

Keywords: scientific literacy, attitudes, beliefs, primary students

1. Introduction

On both a personal and social level, the average citizen has to make daily decisions that require SL (Sharon & Baram-Tsabari, 2020). The recent public health crisis triggered by the COVID-19 pandemic shed light on people's attitudes and beliefs, thus revealing the many shortcomings in citizens' education (Valladares, 2021). The reaction and denial of many individuals to scientific data concerning socio-scientific issues (SSI), for instance, pandemics and global warming, as well as the spread of multiple pseudo-scientific theories, maybe the impetus required to intensify the quest for SL (Nguyen & Catalan-Matamoros, 2020).

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The SL is considered a foundation (Fortus et al., 2022; NASEM, 2016; Roberts, 2007) and a principal purpose of science education for students of education grades (Kampourakis, 2016; Lederman & Bartels, 2018; Lederman & Lederman, 2019; Roberts, 2007). While much research has shown that SL is affected by factors, for instance, age, gender, and socio-economic background, the most consistent factor influencing an individual's SL is education (Archer-Bradshaw, 2017). The cultivation of SL is a key objective of science education (Stylos et al., 2023; Suwono et al., 2022; Yao & Guo, 2018). As such, revising the existing curricula and evaluating teachers' scientific knowledge across all educational levels is necessary for students to acquire science knowledge and skills and adequately cultivate SL (Fives et al., 2014).

Numerous research studies have been performed to assess K-12 students' SL. Several of them clarify the level of SL through questions that require scientific thinking ability in everyday situations and questions about individuals' motivations and beliefs about science. Diana et al. (2015) studied high school students' SL levels. The findings indicate that the SL level is considered extremely poor. Students' motivation and beliefs about science are also rated low. Correspondingly, poor SL performance is observed in similar research by Rachmatullah et al. (2016) and Rohana et al. (2020). However, in the research of Rohana et al. (2020), students' performance in motivational factors is considered good. McKeown's (2017) research shows that students achieve a moderate scientific level. However, their motivation and beliefs toward science are considered good. Finally, a Wilson et al. (2018) survey showed that students performed poorly in SL. This section should describe the general framework, definitions and principles, primary issues and controversies, background information and contexts, etc.

2. Literature Review

2.1 Science and Pseudoscience

Science is a human process (Bybee, 2006) and a means of understanding the world (NASEM, 2016). Three separate but complementary areas define this human process (Lederman & Lederman, 2012, 2019). These are, respectively, the body of knowledge, processes, and methods applied by scientists to construct said body of knowledge and the nature of scientific knowledge (NOSK) (Lederman & Lederman, 2012, 2019).

Science is a method of acquiring knowledge founded on empirical criteria and logical arguments (NRC, 1996). Interpretations and beliefs about phenomena arising from non-scientific documentation processes that claim to be "scientific" are defined as pseudoscience (Losh & Nzekwe, 2011). Pseudoscience, by definition, is an intellectual deceit (Fasce, 2017; Fasce & Picó, 2019). Differentiating science from pseudoscience is especially crucial in a world flooded with pseudo-scientific theories and unreliable media information (Holbrook & Rannikmäe, 2009), as is the case today.

2.2 Nature of Science

As McComas typically mentions, "Nature of Science (NOS) represents the rules of the game of science" (McComas, 2017). NOS is concerned with the understanding of science as a way of knowledge (Khishfe, 2021; Lederman, 1992; Lederman & Lederman, 2019; McComas, 2017), and to the values and beliefs innate to the advancement of scientific knowledge (Abd-El Khalick & Lederman, 2000; Khishfe, 2021; Lederman, 1992).

While there is currently no consensus among scientists on a specific definition of the NOS, there is consensus on the various features that make up the NOS (Khishfe & Lederman, 2006; Lederman, 2007) and describe the process of developing scientific knowledge (Abd-El-Khalick, 2006; Khishfe, 2021; Lederman, 2006). These features are equally adopted by science teachers who teach primary and secondary school students (K-12) (Abd-El-Khalick et al., 1998; Khishfe, 2021; Khishfe & Lederman, 2006; Lederman, 2007). The development of SL is closely related to that of the NOS (Cofré et al., 2019) since to be considered scientifically literate, a person should additionally understand the NOS (Bartels & Lederman, 2022; Lederman et al., 2014).

2.3 Scientific Literacy

The term "Scientific literacy" was first utilised in the late 1950s by Paul Hurd (Hurd, 1958; Laugksch, 2000), and in the decades that followed, many definitions of SL were introduced (Archer-Bradshaw, 2017; Benjamin et al., 2017; Tsoumanis et al., 2023).

Roberts (2007) contends that there are two distinct visions concerning SL. Vision I, also known as "science literacy", refers to the mastery of scientific knowledge and scientific procedures (Roberts, 2007). On the other hand, Vision II, also known as "scientific literacy", refers to individuals' knowledge in science-related matters. Vision II promotes the use of scientific knowledge in decision-making about SSI to adapt to the challenging needs of modern society (Holbrook & Rannikmae, 2009; Roberts, 2007; Lederman, 2019). Vision III has been proposed in recent decades to expand the conceptual scope developed in Vision II (Valladares, 2021). Vision III is based on the educational tradition of Bildung, which originates from Central/Northern Europe. Bildung is an intricate concept that pertains to the development of an individual in dynamic interaction with the surrounding society and broader world (Sjöström & Eilks, 2018). Vision III, also known as critical SL, emphasises the importance of teaching and studying the sciences to transform individuals and society. In particular, it fosters political activity or engagement in SSI (Sjöström et al., 2017).

As stated in the OECD, SL is defined as a person's ability to interact with science-related topics and ideas (OECD, 2017, 2019) as a reflective citizen. A scientifically literate person is described by the OECD (OECD, 2017, 2019) as a person who can participate in science and technology-related public debates and who has the skills to explain scientific phenomena, evaluate scientific research, interpret scientific data, and draw empirical conclusions. The OECD definition is consistent with Vision II, and at the same time, the term "reflective citizen" is included in Vision III (Wang et al., 2019). Furthermore, a scientifically literate person recognises the importance of science, technology, and scientific research in modern culture (OECD, 2017). Last, the scientifically literate person can identify situations in which scientific thinking serves as a decision-making factor, albeit in coexistence with social norms and moral values (Fives et al., 2014).

2.4 The Importance of SL

The importance of science in modern society is reflected in scientific matters governing national and international politics and individual decision-making processes on everyday issues (Fives et al., 2014).

In democratic societies, every citizen has the right to be employed in discussions and the decision-making process of the SSI that concerns them. However, a poor understanding of such issues leads to supporting beliefs contrary to scientific knowledge (Fortus et al., 2022). A fundamental goal of science education is to prepare students to engage democratically, as future citizens, in socio-scientific discussions (Ottander & Simon, 2021). Using SSI in students' evolution as informed and competent citizens requires that scientific education include factual issues of everyday life that go beyond the boundaries of traditional science (Sadler & Zeidler, 2009).

SL, founded on scientific knowledge, empowers individuals to approach science critically and rationally (Osborne & Dillon, 2008; Vieira & Tenreiro-Vieira, 2016). Critical thinking is a fundamental ability that helps people make decisions about everyday situations through emotional states and cognitive abilities (Ennis, 1996, 2018), not based on personal experiences or beliefs (Yacoubian, 2020). Moreover, individuals develop skills of interpretation, evaluation, and the ability to conclude scientific issues and information from scientific publications (OECD, 2016b), news, or digital media, which are often a source of scientific education (Fives et al., 2014) but may equally spread fake news and misinformation (Nguyen & Catalan-Matamoros, 2020).

On a national level, the cultivation of SL determines a nation's competitiveness and economic well-being (Dillon, 2009). According to PISA data, adolescents' scientific knowledge and the economic prosperity of nations are significantly linked (Fortus et al., 2022). It also seems that students' performance in science foretells economic prosperity for nations (Hanushek & Woessmann, 2015). At the same time, national research and development strategies can support scientifically trained talent, ultimately leading to lower unemployment rates and higher living standards (NASEM, 2016).

2.5 Socio-Demographic Factors Affecting SL

2.5.1 Gender

Gender differences in developing an interest in science and mathematics, both academically and professionally, are often formed in early adolescence (Steegh et al., 2019). Such differences become even clearer when attending secondary education (UNESCO, 2017; Lai, 2010; Marx & Roman, 2002), and findings have shown that differences in science-related interests, abilities, and performance between genders are not justified by genetic or biological factors (Good, Woodzicka & Wingfield, 2010; Karaoglou & Kotsis, 2017). Additionally, stereotypical societal views often create and widen the gender gap (OECD, 2016a). Such gender stereotypes refer to girls' lack of scientific knowledge compared to boys, arguing that a scientific career suits boys or men (Hill et al., 2010). From a scientific perspective, studies confirm ambiguity over gender performance in science. Some findings show that men (or boys) perform better than girls (or women) (Hayes & Tariq, 2000; Louis & Mistele, 2012; Garner et al., 2014; Reilly et al., 2015; Karaoglou & Kotsis, 2017). Other studies show that there are no significant differences between genders (OECD, 2016a; Naganuma, 2017), while according to the OECD's gender data, girls outperform boys without the difference being considered statistically significant (OECD, 2019).

2.5.2 Urban Environment

The impact of urban or rural areas on students' academic performance remains uncertain (OECD, 2016c). Some factors that play a role include the school's geographical location, cultural homogeneity, parental educational background (Bæck, 2016), and the availability of educational and financial resources in schools (OECD, 2016c). According to PISA research, on average, across all OECD countries, students in rural areas appear to perform worse than those in urban areas. While the above association is not statistically significant, geographic location remains an important factor influencing the extent of students' SL (OECD, 2016c).

2.6 Attitudes, Motivations, and Beliefs towards Science

2.6.1 Value of Science

In line with the expectation-value theory (EVT), students' expectation for success and achievement of personal goals combined with the level that they believe an academic task is worth pursuing (task value) predicts student motivation (Eccles & Wigfield, 2002). Subjective task value refers to the value students attach to their academic work and consists of four aspects: attainment value, intrinsic value, utility value, and cost (Brown et al., 2015; Eccles & Wigfield, 2002; Shin et al., 2019). Understanding the usefulness of science can increase students' motivation to engage in scientific topics (Shin et al., 2019). The appreciation of science's value, both on a personal and social level, is an important trait of scientifically literate individuals and, therefore, an important factor in achieving SL (Fives et al., 2014).

2.6.2 Self-efficacy in Science

Self-efficacy refers to an individual's confidence in their capacity to perform actions to solve a problem or accomplish a task (Bandura, 1997). At the academic level, there appears to be a consistent and causal relationship between self-efficacy and academic performance (Honicke & Broadbent, 2016; McBride et al., 2020; Schneider & Preckel, 2017). This association determines a student's judgment of their capability to attain educational objectives (Honicke & Broadbent, 2016), and influences student participation in the educational process and future career choices (Webb-Williams, 2018). Self-efficacy in science specifically regards' a person's beliefs about their abilities to achieve specific goals, which require scientific knowledge and skills (Mason et al., 2013; McBride et al., 2020; OECD, 2016a). According to the literature, a positive relationship exists between students' self-efficacy beliefs about science and students' performance in both Science and Mathematics (Dorfman & Fortus, 2019; Lin et al., 2013; McBride et al., 2020).

2.6.3 Personal Epistemology

Personal epistemology is a psychological construct that examines an individual's beliefs about knowledge and knowing (Hofer, 2001). It refers to what people think knowledge is, how they interpret, evaluate, and justify knowledge, and how they develop knowledge (Hofer, 2001; Hofer & Bendixen, 2012). Epistemological beliefs consist of four dimensions: two dimensions concern the nature of knowledge, and two dimensions concern the nature and process of knowing, that is, how one learns (Hofer, 2000). It has generally been observed that individuals' epistemological beliefs develop over time. It has also been highlighted that advanced epistemological beliefs help develop critical thinking, conceptual understanding, and decision-making skills, activate learning motivation, and effectively evaluate information (Hofer & Sinatra, 2010; Muis & Franco, 2010).

3. Present Study

This study's purpose is threefold. It set out to:

1) validate the Greek version of the SL Assessment (SLA) tool,
2) examine the SL level among sixth-grade primary school students, and
3) evaluate students' motivation and beliefs about science.

Moreover, the validity of the research tool in a Greek educational setting will be investigated. Therefore, the questionnaire followed specific translation procedures into Greek, and an exploratory factor analysis (EFA) was performed. Moreover, the Kuder-Richardson 20 (KR-20) and a-Cronbach cohesion and reliability indicators were calculated. In line with the study's purpose, there are four research questions the data shall attempt to answer:

1) Determine the dimensionality of the measure for SL,
2) Assess students' SL levels,
3) Assess students' motivation and beliefs about science,
4) Establish any significant differences in performance on the SLA based on demographic factors.

4. Material and Methods

4.1 Participants

The current study involved a total of 455 sixth-grade students, comprising 237 girls and 213 boys. The sample was selected by convenient sampling and consisted of students from nineteen schools in different geographical districts throughout Ioannina, Greece. The geographical areas were defined based on the relevant PISA criteria (OECD, 2019c).

4.2 Instrument

The SL Assessment (SLA) tool was developed to assess SL by gauging individuals' scientific capacity, motivation, and beliefs toward science. It was developed by Fives et al. (2014) with the primary objective of appraising the SL of students aged 11 to 14 years.

There have been many SL assessments in which various questionnaires have been used. Based on a re-conceptualized SL framework, Mun et al. (2015) developed an instrument they call the Global SL Questionnaire (GSLQ). Gormally et al (2012) developed the Test of SL Skills (TSOLS) framework. Both instruments' aim is not to assess the students' knowledge about specific science subjects but instead concentrate on using scientific knowledge and procedures to cope with the issues and challenges we encounter in daily life, which is consistent with our view of SL. However, the Fives et al. (2014) SLA is a questionnaire that combines examples and contains questions with everyday examples and motivational aspects related to science. Specifically, this questionnaire was chosen because it does not focus on one specific field/discipline, as it evaluates "students' motivation for and beliefs about science" and incorporates mathematics as "working knowledge" in science (Fives et al., 2014). Until now, the research tool has been used in Greece to assess preschool primary teachers' SL (Stylos et al., 2023). The authors' team discussed and concluded that students can also answer the questions to make a comparison. The SLA instrument consists of two distinct measures. The SLA-D is comprised of 26 multiple-choice items designed to assess SL. These items utilize everyday situations and examples to evaluate participants' comprehension of various aspects, including science's role, scientific thinking and practice, the role of science in society, science media literacy, and mathematics in science (Fives et al., 2014). The SLA-MB evaluates students' motivations and beliefs toward science. This evaluation tool comprises 25 items across a 5-point Likert scale. It is organised within three categories: value of science, self-efficacy (what I can do in science), and personal epistemology (what I believe about science). Demographic variables (e.g., gender, age, ethnicity, urban environment, and type of school) were also included in the questionnaire. The SLA was translated into Greek and adhered to the guidelines set by the International Test Commission (ITC) for test adjustment (Hambleton, 2001) and incorporated recommendations from Beaton et al. (2000). The process involved the translation of items from the initial version into Greek by two languages speakers. Then, terminology adjustments were implemented to address inconsistencies identified during the back translation. Additionally, a panel of scholars and experts in the specific research field scrutinised each item for face validity, content relevance, and cultural appropriateness. Minor wording changes were also introduced to ensure age appropriateness.

4.3 Pilot Study

A pilot study was conducted in a sample of the target population of 25 sixth-grade students (12 girls and 13 boys). The translated version of the SLA was examined for age and ability appropriateness of meaning understanding and linguistic accuracy. Furthermore, the time required for questionnaire completion and any difficulties in understanding scientific concepts were considered. According to the pilot study's findings, the average time participants were required to complete the questionnaire ranged between 50 minutes and 1 hour. Adjustments were then made according to participant feedback, leading to the finalisation of the questionnaire.

4.4 Main Study

The main study initially included 430 sixth-grade students from nineteen primary schools in Ioannina, Greece. Data collection started in January 2020. The questionnaires of five students were not considered during the analysis as they had missing responses in the SLA and the section on demographic characteristics. The final sample consisted of 425 students (225 girls and 200 boys) ages 11-13 years (M=11.5, SD=.523).

While the pilot survey confirmed an estimated 50–1 hour time frame to complete the questionnaire, no time limit was imposed on the main study group. After completion, student questionnaires were collected and scored.

4.5 Statistical Data Analysis

An Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis CFA were conducted to determine the multidimensionality of the measurement model for SL.

Firstly, negatively formulated items of the SLA-MB were re-coded by reversing the score (1=5, 2=4, 3=3, 4=2, 5=1). Of all the SLA-MB items, 11 of the "What I believe about science" category had reverse scores (Conley et al., 2004).

Principal component analysis (PCA) with orthogonal Varimax rotation determined correlations between the variables (Value of Science, Self-efficacy, Personal Epistemology). Factors with structure coefficients of .30 or greater were considered significant (Stevens, 1992). In addition, the Kaiser-Meyer-Olkin Test (K.M.O) for sampling sufficiency coefficient and Bartlett's test of sphericity (Bartlett, 1950) were measured. Acceptable values for the KMO were considered those greater than 0.70 (Field 2013).

The assessment tool's internal consistency was also investigated. Regarding the SLA-D, we considered the previous reliability measure conducted on the same sample of students (Tsoumanis et al., 2023). Although Kuder-Richardson coefficient is considered moderately reliable (0.65-0.68), it is acceptable for cognitive research (Chu et al., 2012; Glen, 2023; Tsoumanis, 2021; Stylos et al., 2021). The internal coherence of the SLA-MB factors was tested using Cronbach's alpha coefficients (Field, 2013).

Specific statistical indices such as mean score and standard deviation of SLA-D and SLA-MB were calculated. Subsequently, appropriate tables were created for visual representation.

Additionally, a regression analysis was conducted to assess the impact of variables such as gender or urban environment on the score. The regression analysis adopted a linear model to predict the values of a dependent variable from one or more predictor-independent variables. The multiple regression technique is adopted when several predictors are included in the model (Field, 2013; Uyanık & Güler, 2013).

Finally, descriptive analyses and statistical hypothesis testing such as independent t-test, one-way ANOVA, and non-parametric tests were carried out to discover any differences in the average scores of two distinct SLA measures according to the socio-demographic characteristics of the participants. The choice of the statistical significance test depended on the normality test performed on the sample. Statistical tests and graphs such as histograms and boxplots confirmed the normality assumption. In situations where the normality hypothesis was not met, non-parametric tests were conducted (Field, 2013; Koutsianou & Emvalotis, 2019).

5. Results

5.1 Descriptive Statistics

The research sample involved 425 students from nineteen primary schools across the Ioannina, Greece Regional Unit. 52.9% of students were girls and 47.1% were boys. 11.5% of participants lived in rural areas, 15.5% in suburban areas, and 72.9% in urban areas.

5.2 Exploratory Factor Analysis (EFA)

The SLA-MB items underwent a PCA for examination. Items 32 and 44 were excluded as they had loading on two factors. Therefore, 23 items of SLA-MB remained on which principal component analysis (PCA) was again performed. The suitability of the data for factor analysis confirmed by KMO was 0.83, and Barlett's test of sphericity was statistically significant ($\chi 2$ (253) =1900.115, $p<.05$). According to EFA results, three factors with eigenvalues above 1.00 were observed. The preservation of the first three factors was confirmed by the Scree Plot, in which we observed a distinct decrease in the slope of the curve from the third factor onwards (Tsoumanis, 2021).

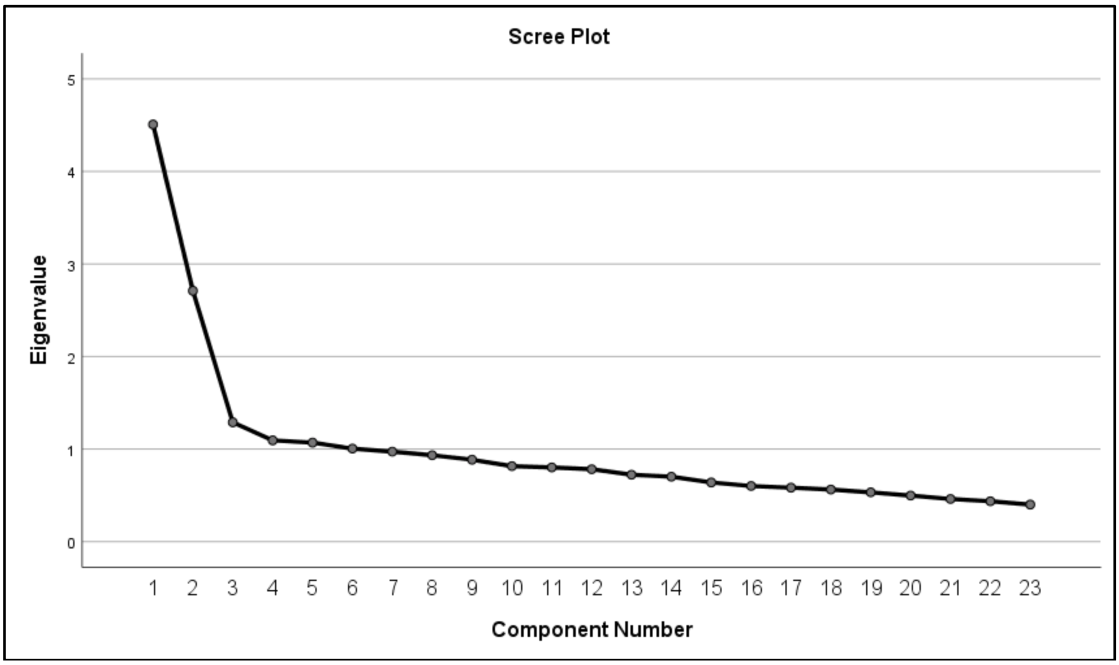

Figure 1: Scree Plot

These three factors explained 36.98% of the variance. The classification of items was based on their factor loading, organised in descending order, and subsequently categorised in accordance with each specific factor. The factor loadings following rotation are illustrated in Table 1. The items of the first factor concern the personal epistemology category (What I believe about science) and explain 19.59% of the variance. The items loaded in the second-factor items describe the Value of Science category and explain

11.78% of the variance, and the third-factor items represent the Self-efficacy category (What I can do in science) and explain 5.9% of the variance.

Table 1: Summary of SLA-MB items and factor loadings

	Factor Loading		
	Personal Epistemology	**Value of Science**	**Self-efficacy**
47. Scientists pretty much know everything about science; there is not much more to know.	.694		
49. Once scientists have a result from an experiment, that is the only answer.	.628		
51. Only scientists know for sure what is true in science.	.619		
46. Whatever the teacher says in science class is true.	.597		
42. All questions in science have one right answer.	.567		
50. Scientists always agree about what is true in science.	.542		
48. If you read something in a science book, you can be sure it's true.	.520		
41. Everybody has to believe what scientists say.	.516		
43. Scientific knowledge is always true.	.510		
45. The most important part of doing science is coming up with the right answer.	.368		
30. Compared to most of your other activities, how important is it for you to be good at science?		.691	
29. For me, being good in science is.		.684	
28. Compared to most of your other activities, how useful is what you learn in science?		.659	
31. How much do you like doing science?		.620	
27. In general, I find working on science assignments.		.584	
39. I can tell the difference between observations and conclusions in a story.			.617
38. I can use math to answer scientific questions.			.615
37. When I do my work in science class, I am able to find the important ideas.			.583
33. I know when to use science to answer questions.			.564
40. It is easy for me to make a graph of my data.			.519
34. I can use science to make decisions about my daily life.			.518
35. I know how to use the scientific method to solve problems.			.448
36. It is easy for me to tell the difference between scientific findings and advertisements.			.350

5.3 Confirmatory Factor Analysis (CFA)

A Confirmatory Factor Analysis (CFA), using AMOS, was performed to test the fitness of the proposed model. Furthermore, items' factor loadings were examined. Adjustments measures were employed to estimate the overall goodness of the model, including CMIN/df, GFI, CFI, TLI, SRMR, and RMSE, and all values fell within acceptance ranges (Ullman, 2001; Hu & Bentler, 1999; Stylos et al., 2022). The factor model (value of science, self-efficacy for SL, personal epistemology of science) submitted a satisfactory fit for the data: CMIN/df= 2, GFI=0.92, CFI= 0.93, TLI=0.92, SRMR=0.6, and RMSEA=0.05. The chi-square test was statistically significant (χ^2 =516.603, df = 257, p =.000).

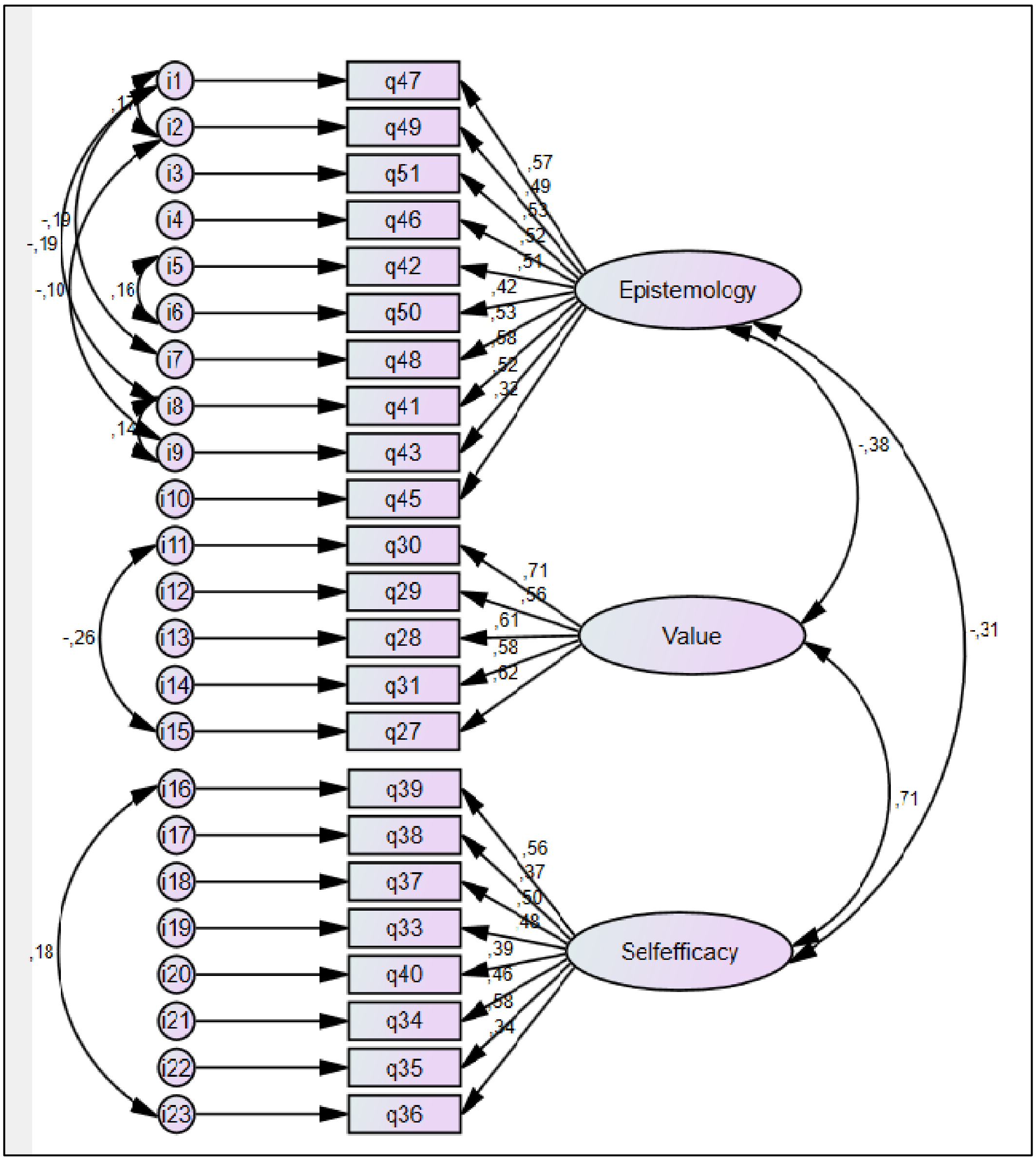

Figure 2: Confirmatory factor analysis on the "SLA-MB" questionnaire

5.4 Exploratory Factor Analysis of the SLA-D

A PCA was executed in order to identify the factor structure SLA-D items. According to normality hypotheses tests, there is a non-normal distribution (p < 0.001). In addition, each item's skewness and kurtosis suggest that the variance adhered to acceptable guidelines (West et al., 1996). Most correlations among items were less than 0.3, signifying that factoring is not particularly helpful (Beavers et al., 2013). The KMO was .757, and Bartlett's test was statistically significant (937.725, $p < .05$) without rotation. At last, a parallel analysis demonstrated that the SLA-D is one-dimensional (McKeown, 2017).

5.5 Reliability Analysis

The KR20 coefficient was .66, indicating moderate reliability but acceptable in cognitive research (Chu et al., 2012; Glen, 2020). Internal consistency of the overall SLA-MB questionnaire was .639. The factors of the value of science, self-efficacy in science, and personal epistemology had Cronbach's reliability at a= .732, .686, and .767, respectively. The number of items, α-Cronbach reliability coefficients, and percentage of total variance are summarised in Table 2.

Table 2: SLA-MB Questionnaire: a-Cronbach and % of total variance

Factors	N (Items)	Cronbach's Alpha	Total Variance (%)
Personal Epistemology	10	0.767	19.59
Value of Science	5	0.732	11.78
Self-efficacy	8	0.686	5.60

According to the discrimination indices, the SLA-D items ranged between 0.33 and 0.57, with a mean of 0.37 and a median of 0.41. 80% of participants responded correctly to item 19, but only 8% to item 1. More than 50% of students answered correctly to 20 out of the 26 items.

5.6 Regression Analysis

The association between the independent variables (gender, urban setting) and the dependent variable (Score) was further examined through the multiple linear regression technique. According to the results, there is a feeble positive correlation (R=.236) among the scores in the SLA-D and the independent variables. However, the predictors did not affect outcome variability as they explained only 4.9% of the variance (R^2=.049). All predictors had positive b-values, indicating positive relationships. Moreover, according to the p-value predictors, there was a statistically significant impact on the independent variable (Table 3). It is observed that gender (b=5.2) and urban environment (b=7.9 and b=5.9) were positive predictors of students' average scores. Results in the "Value of science" motivation and belief scale yielded no significant association between the average score and independent variables, as the latter explained only 1.6% of the total variance (R^2 = .016) (Table 4). Similarly, the predictors for "Self-efficacy" explain 3.1% of the variance (R^2 = .031) (Table 5). Finally, urban environment (β= 6.9) is a weak positive predictor of students' average score in "Personal epistemology" as it interprets 5.8% (R^2 = .058) of the total variance (Table 6).

Table 3: Regression analyses among the SLA-D and socio-demographic variables

Dependent variable	Independent variables	B	t	R	R^2	p
Score (SLA-D)	Gender	5.181	3.625	.236	.049	.000
	Urban area	7.889	3.494			.001
	Suburban area	5.936	2.141			.033

Table 4: Regression analyses among the SLA-MB (Value of Science) and socio-demographic variables

Dependent variable	Independent variables	B	t	R	R^2	p
Score (SLA-MB Value)	Gender	5.504	3.118	.151	.016	.002
	Urban area	-.201	-.072			.943
	Suburban area	.913	.266			.790

Table 5: Regression analyses among SLA-MB (Self-efficacy) and socio-demographic variables

Dependent variable	Independent variables	B	t	R	R^2	p
Score (SLA-MB Self-efficacy)	Gender	4.316	3.492	.193	.031	.001
	Urban area	2.481	1.270			.205
	Suburban area	-.436	-.182			.856

Table 6: Regression analyses among the SLA-MB (Personal Epistemology) and socio-demographic variables

Dependent variable	Independent variables	B	t	R	R^2	p
Score (SLA-MB Epistemology)	Gender	2.218	1.466	.254	.058	.143
	Urban area	6.957	2.911			.004
	Suburban area	-2.838	-.967			.334

5.7 Descriptive Analysis and Hypothesis Test

5.7.1 SLA-D

Boys achieved a mean score of 38.31 (SD=14.75), and the girls 43.33 (SD=14.95). To explore if any statistically significant differences between the scores by students' gender exist, a Mann-Whitney test was executed. According to the results, a statistically significant difference exists between boys' and girls' mean scores on the SLA-D, U = 27102.5, z = 3.654, p = .000, r = .176. Regarding the urban environment, students in urban areas achieved a higher mean score (M = 42.20, SD = 15.09), followed by those living in a suburban area (M = 39.92, SD = 15.72 and finally students living in a rural area (M = 34.62, SD = 12.11). Furthermore, the Kruskal-Wallis test was conducted to examine any potential differences between students' scores according to geographic location. The results revealed significant differences between the three geographic locations and students' mean score, H (2) = 10.528, p=.005.

5.7.2 SLA-MB

The results of the SLA-MB about gender show a significant difference in favour of girls on scales "Value of science" U = 26425.0, z = 3.115, p = .002, r = .151 and "Self-efficacy", U = 27067.500, z = 3.622, p <.05, r = 0.175. The scores on the "Personal epistemology" scale showed no differences between boys and girls, U = 24262.500, z = 1.396, p = .163, r =. 067. Regarding the urban environment, it seems that there is no statistically significant difference between the school's geographic location and the "Value of science", H (2) =. 418, p = .811 and "Self-efficiency" scales, H (2) = 3.990, p = .136. However, the "Personal epistemology" scale showed a statistically significant difference in responses depending on whether schools were located in urban environments H (2) = 23.905, p <.05.

Table 7: Descriptive statistics of variables (%)

Scores	Mean		Range	Minimum	Maximum	Std. Deviation
	Statistic	Std. Error	Statistic	Statistic	Statistic	Statistic
Performance (SLA-D)	40.97	.73	73	12	85	15.05
Value of Science	75.89	.88	100	0	100	18.28
Self-efficacy	69.32	.63	100	0	100	12.89
Personal Epistemology	59.27	.77	100	0	100	16.00

Table 8: Differences in the SLA-D and SLA-MB between genders

Aspects	Boys (M-SD) (%)		Girls (M-SD) (%)		U	*Z*	*p*
SLA D	38.31	14.75	43.33	14.95	27102.5	3.654	.000
Value of Science	73.00	16.33	78.47	16.93	26425.0	3.115	.002
Self-efficacy	67.03	13.74	71.37	11.73	27067.5	3.622	.000
Personal Epistemology	58.01	16.64	60.39	15.36	24262.5	1.396	.163

Table 9: Differences in the SLA-D and SLA-MB between geographic areas

Aspects	Rural (M-SD) (%)		Suburban (M-SD) (%)		Urban (M-SD) (%)		H	*df*	*p*
SLA D	34.62	12.11	39.92	15.71	42.20	15.09	10.528	2	.005
Value of Science	76.24	17.40	76.48	20.12	75.71	18.06	.418	2	.811
Self-efficacy	67.85	11.43	66.89	17.05	70.08	12.01	3.990	2	.136
Personal Epistemology	54.77	15.04	51.66	15.29	61.60	15.68	23.905	2	.000

6. Discussion-Conclusion

This study aims to validate the Science Literacy Assessment (SLA) tool and evaluate the SL level among primary school students according to socio-demographic factors. The outcomes of the Exploratory and Confirmatory Factor Analyses validate a one-dimensional structure for the SLA-D and a three-dimensional construct for the SLA-MB. This finding aligns with comparable research findings (Fives et. al., 2014; McKeown, 2017). Regarding reliability, the Kuder-Richardson coefficient indicates that the SLA-D is a reliable research tool. However, the Cronbach alpha coefficient for the SLA-MB renders it questionable (0.639). For each component taken separately, the indicators are considered acceptable, and the approach is satisfactory, as per the findings of Fives et al. (2014).

6.1 SLA-D

According to the results, students' mean scores in SLA-D are overall low, and this finding is similar to that of Rohana, Asrial, and Zurweni (2020). However, compared to the majority of equivalent studies (Tsoumanis et al., 2023), students' average score was significantly lower and characterised as very poor (≤54%). However, it is crucial to highlight that the age of students involved in the current study was younger than participants in other studies.

Regarding gender, girls have a clear lead and were found as statistically significant. This finding contradicts the research results of Rachmatullah, Diana, and Rustaman (2016). In Greece, the superiority of girls is also observed in the results of the PISA 2015 and 2018 (OECD, 2016a; Sofianopoulou et al., 2017; OECD, 2019a). Also, in Greece, it has been observed that students in urban areas achieve higher scores than those in suburban or rural areas (Sofianopoulou et al., 2017). The present research confirms the above claim, as students in urban areas achieved significantly higher scores than students in suburban or rural areas.

6.2 SLA-MB

6.2.1 Value of Science

Several studies on the value expectation theory (EVT) have highlighted how critical it is to enhance students' motivation to engage in science (Brown et al., 2015; Shin et al., 2019). In the current survey, students showed positive attitudes about the value of science. These findings align with results obtained in other studies (Tsoumanis, 2021). In general, student's attitudes about the usefulness of science can be characterised as highly positive. Students' attitudes toward attaining the value of science are also quite positive. Finally, students show positive attitudes but, to a lesser extent, in the intrinsic value of science. Although the perceptions of both genders are optimistic, girls show significantly more positive attitudes than boys. Girls seem to consider the usefulness of science; however, they assign less importance to its intrinsic value. Finally, the school's geographic location did not influence students' attitudes, as these were positive across urban, suburban, and rural areas.

6.2.2 Self-efficacy

Relating to self-efficacy in science, the findings in the present study showed that students fare quite well. Since self-efficacy predicts commitment and persistence in a general task or activity (Pajares, 1996), strong science self-efficacy implies a higher probability that students will actively participate in everyday scientific endeavours and approach critical thinking about the world surrounding them (McBride et al., 2020). Studies have shown that science self-efficacy does not differ concerning gender (Karaarslan & Sungur, 2011; Kiran & Sungur, 2012). For example, findings from the research of McBride et al. 2020 only showed minimal quantitative differences between genders, with women performing marginally better. The study by Sezgintürkem and Sungur (2020) led to similar findings. However, their findings highlighted that boys showed slightly higher levels of self-efficacy. Meanwhile, the Webb-Williams (2018) study showed that despite similar beliefs between genders, girls tended to exhibit reduced levels of science self-efficacy. Similar findings emerged from the studies of Lin and Tsai (2018) and Usher et al. (2019). Moreover, in the current study, variations in self-efficacy based on gender were identified. Girls showed significantly greater levels of self-efficacy than boys.

The local environment is likely to expose students to more experiences and, therefore, boost their self-efficacy (Usher et al., 2019). In the current study, students' self-efficacy level was good across all three geographic areas. Students in urban areas possess slightly higher self-efficacy levels than students in suburban or rural areas; however, this difference is not considered significant.

6.2.3 Personal Epistemology

Personal epistemology is a crucial component of the learning procedure (Alpaslan, 2017). In a study by Conley et al. (2004), participants contended that knowledge is uncertain and that there can only be one correct answer to science. In the present research, students' views on the certainty of knowledge seem neutral. However, they also seem to lean toward the view that knowledge is not fixed or absolute. Students, in general, also seem to show neutrality over their confidence in what scientists say, as the continuous development of scientific knowledge creates conflicting views among scientists (Barger et al., 2018) and, depending on the views of scientists, can prevent students from engaging in individual science.

Regarding gender, the present study's findings do not show significant differences in personal epistemology, reinforcing the claims of similar research (Conley et al., 2004; Liu & Tsai, 2008). Regarding geographic location, it seems that students in urban areas differ significantly on personal epistemology in relation to students in suburban and rural areas. Different epistemological beliefs are likely to be shaped by the diverse lifestyles of people living in urban areas (Mohamed, 2014). The results of the present study show that the level of SL ranges from moderate to low. Students cannot adequately use their scientific thinking to deal with everyday science-related situations. Students' attitudes and beliefs about science, however, are satisfactory. Students seem to recognise the usefulness of science. Also, students' beliefs about their self-efficacy can be a catalyst/prognostic factor in their involvement in science. Finally, students' attitudes towards knowledge and knowing are associated with their willingness to acquire knowledge. In addition, the results demonstrate a significant positive correlation between the average score on the value of science and self-efficacy. This is in line with research about EVT, which shows that students typically report appreciating assignments that they are certain they can do (or the opposite) (Fives et. al., 2014). The higher SL level of girls can be interpreted by the tendency to reduce stereotypes over women's representation and performance in the sciences. It also shows the increased interest of girls and young women in science. As for the school's geographic location, significant differences in student performance seem to exist for questions related to everyday situations. However, there is no significant difference in student attitudes and beliefs about science according to the school's geographic location.

7. Limitation and Further Research

The sample was selected by convenient sampling method and from a single prefecture in Greece. As a result, the sample does not represent a wide range of primary school students. Moreover, most participants went to schools in urban areas. Therefore, the results do not justly represent the diversity of locations. Future research could examine SL levels between students across all education grades. Moreover, the influence of factors, including socio-economic background and cultural capital, could also be considered.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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