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Primary education students' scientific literacy in terms of some variables

Ivo Yuliana[1]*, Budi Jatmiko[2], Wahono Widodo[3], Suryanti[4], Irwanto[5]
[1,4]Departement of Primary Education, Universitas Negeri Surabaya, Surabaya, Indonesia, ivoyuliana@unesa.ac.id (I.Y.) suryanti@unesa.ac.id (S.)
[2]Study Program of Physics Education, Universitas Negeri Surabaya, Surabaya, Indonesia, budijatmiko@unesa.ac.id (B.J.)
[3]Departement of Science Education, Universitas Negeri Surabaya, Surabaya, Indonesia, wahonowidodo@unesa.ac.id (W.W.)
[5]Department of Chemistry Education, Jakarta State University, Surabaya, Indonesia, Irwanto@unj.ac.id (I.)

Abstract: In numerous countries, including Indonesia, the primary objective of Primary Education has evolved to prioritize attaining scientific literacy. This study investigates the scientific literacy of pupils, examining variations by gender and grade level upon completion of science instruction. In this academic study, the coefficient sampling technique was employed to choose a cohort of 629 pupils from ten educations in the East Java province of Indonesia. The study methodology involved conducting a survey and gathering data by administrating the Scientific Literacy Test (SLT). The outputs of this study show that scientific literacy (SL) among Primary Education pupils is at a relatively low stage. Notable disparities in academic performance were studied based on gender and grade level. Interestingly, the commonly held social belief that men excel more than women in science did not appear applicable among the student population. Hence, it is imperative to conclude that before commencing Primary Education instruction, educators should assess the scientific literacy competencies of their pupils. A policy position about SL-in-action is developed and analyzed, considering the considerations that would confront decision-makers who shape the school's primary curriculum policy.

Keywords: *Gender, Grade level, Primary education, Scientific literacy, Survey.*

1. Introduction

In recent decades, the global focus on science education has shifted towards enhancing scientific literacy. This objective aims to cultivate the essential abilities and knowledge necessary for individuals to confront the demands of the contemporary world, including advancements in technology that necessitate a grasp of scientific concepts and critical thinking [1-4]. The significance of introducing scientific literacy (SL) at an early stage extends beyond addressing everyday challenges; it serves as the cornerstone for nurturing highly competent individuals in the realm of science [5]. Ultimately, this endeavor contributes to the increase of a nation's economic growth [6]. However, several different points of view define scientific literacy [7]. As defined by the PISA, scientific literacy encompasses actively connecting with science topics and grappling with scientific concepts while embodying the qualities of an informed and thoughtful citizen [5]. In line with Nursalim, et al. [3] and Yuliana, et al. [8] it is the aptitude for applying scientific knowledge, identifying inquiries, and formulating proof-based conclusions in real-life situations to facilitate informed decision-making. The scientific literacy assessment design established by PISA comprises three key competencies: recognizing scientific issues, providing scientific explanations for specific events, and using scientific proof [9].

In Canada and Australia, Luu and Freeman [10] analyzed the correlation between scientific literacy abilities and information and communication technology (ICT) involving 15-year-old pupils in each country. The study results show that there is quite a significant correlation among these variables. It is

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* Correspondence: ivoyuliana@unesa.ac.id

also emphasized that pupils who use computers in education to achieve studying outputs might have a more decisive influence on scientific literacy than how frequently the computer is accessed. In contrast, a study in Turkey by Kaya, et al. [11] examined the correlation between scientific literacy and science procedure abilities among 70 primary education pupils. The outputs revealed no disparities in the stage of scientific literacy based on pupils' science procedure abilities.

Furthermore, a highly positive and meaningful association was studied among science procedure abilities, values, and stages of scientific literacy. Finally, Mbajiorgu and Ali [12] in a study involving 246 pupils in Nigeria and examining the connection among the Science, Technology, and Society (STS) approach, scientific literacy (SL), and biology studying accomplishment, they found that the STS approach serves as a mediator among SL and Accomplishment, by a slightly firmer, noteworthy, and positive connection. It implies that scientific literacy abilities have been demonstrated to increase student studying accomplishment in and beyond the education environment.

Prior study has documented the potential effect of gender [4, 9, 13-19] grade level [11, 16, 20-23] regarding scientific literacy abilities. Based on PISA [5] reports, the mean gender difference in science is the smallest among other countries. Among the countries and regions considered, such as Argentina, Beijing, Shanghai, Jiangsu, Zhejiang (China), Colombia, Costa Rica, Mexico, and Peru, it is studied that males outperform females in science. Conversely, the reverse trend is evident in 34 other countries and economies. In Turkey, Kaya, et al. [11] Investigated the correlation between scientific literacy and scientific procedure abilities among 70 primary education pupils in classes 6, 7, and 8. The outputs revealed that, based on the outputs of the scientific study, the pupils in class 7 exhibited a more favorable combination of literacy stages and scientific procedure abilities than the other classes.

Several studies reveal pupils' scientific literacy abilities [15, 24-27] scientific literacy in primary education [3, 8, 28, 29] college stage [30, 31]by gender [9, 16, 17] by grade level [4, 11, 22, 32]. Nevertheless, no existing study has concurrently examined primary education scientific literacy considering gender and grade level. Consequently, this study analyzes pupils' scientific literacy abilities by considering two key factors: gender and grade level. In light of this, the following study questioning has been designed:

a) What is the stage of scientific literacy of primary education pupils?
b) Are there gaps in pupils' scientific literacy skill values based on grade level and gender?

2. Literature Review

2.1. Scientific Literacy

Scientific Literacy (SL) represents a fundamental cornerstone in the realm of 21st-century education, inseparable from the domain of science instruction [31, 33, 34]. Numerous individuals view the acquisition of scientific literacy abilities as an objective in the field of science education [35-37]. Hence, the cultivation of scientific literacy (SL) holds the promise of having a constructive effect on the effectiveness of science education, particularly on the events of primary education pupils. A total of previous studies confirmed the existence of a correlation between scientific literacy abilities and science procedure abilities [10] [31, 38-42] critical thinking [43] mastery of concepts [44] and creativity [45]. Using scientific literacy, pupils connect in authentic science education that fosters curiosity. Effective science instruction can be achieved by integrating procedure abilities concurrently [46, 47].

Scientific literacy abilities as a key factor in student academic accomplishment [12, 24, 48] according to [37], state that SL acquisition increases along with cognitive development. In line with Cavagnetto [26] and Pamungkas, et al. [32] Scientific literacy is achieved through comprehension of scientific principles, procedures, and arguments, underpinned by cognitive and metacognitive procedures, and critical reasoning and communication abilities. Enhancing scientific literacy abilities can be accomplished by investigating problems or events. Aligning with [49] who highlighted the significance of integrated studying, which involves the exploration of intricate issues or events by a focus on studying activities encompassing, but not restricted to, the practice of formulating questions

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and empirically investigating them through necessity-based studying [43, 50, 51]. This assertion finds support in Oliver, et al. [27] where an intricate connection pattern between pupils' scientific literacy and various facets of the necessity component was identified based on data collected by six countries in the context of PISA 2015. Looking at LS competencies following [5] it becomes evident that it is necessary and integral to conceptualizing and operationalizing PISA scientific literacy [52].

3. Methodology

3.1. Research Design

This study was utilized as a quantitative survey. In this context, a survey is a data collection method to gather information from individuals and encompass crucial details, beliefs, opinions, attitudes, motivations, and behaviors [53-57]. Mainly, it collects data about Scientific Literacy Test (SLT) performance among primary education pupils, focusing on grade level and gender distinctions. It was administered after the completion of science instruction, as it was considered essential to examine pupils' acquisition of scientific literacy and assess the effectiveness of the instructional model implemented for one semester. The outputs of this study can serve as a resource for educators seeking to increase pupils' scientific literacy by adopting alternative, potentially more effective, instructional models.

3.2. Participants

This study included 629 primary education pupils in classes 4 and 5, aged 10-12 years, in the 2023/2024 academic year. They were chosen using convenience sampling, a non-probability sampling technique employed when the study population is readily accessible and suitable for its purposes [58]. In this survey, no pupils were rejected for use as study samples. Therefore, all 629 pupils explored in this study provided trusted information.

Table 1.
Sample distribution.

Gender	N	Percentage
Male	228	36.24
Female	401	63.76
Total	629	100
Grade levels		
Fourth class	319	50.72
Fifth class	310	49.28
Total	629	100

3.3. Instrument

In the 2023/2024 academic year, this study included 629 primary education pupils in classes 4 and 5, aged 10-12 years, who were chosen using convenience sampling. Convenience sampling is a non-probability sampling technique employed when the study population is readily accessible and suitable for the study's purposes [58]. In this survey, no pupils were rejected for use as study samples. Therefore, all 629 pupils explored in this study provided trusted information.

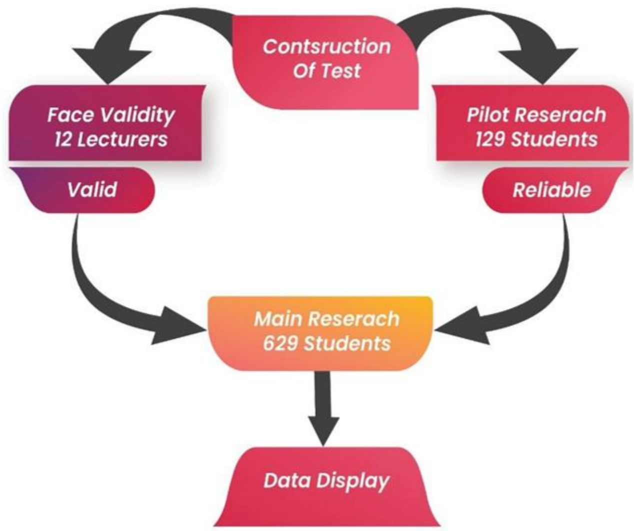

Figure 1.
The procedure of data collection.

The Scientific Literacy Test (SLT) assessed scientific literacy among primary education pupils. The SLT comprises nine questions, each including three indicator questions. The scoring range for the SLT ranges from a min. of 5 to a max. of 30. The Cronbach's alpha reliability coefficient for the every parts scale is 0.79, with sub-scales describing certain events scientifically at 0.79, analyzing and framing scientific investigations at 0.77, and delivering data and proof scientifically at 0.78. These coefficients suggest that the SLT is a trusted and reliable tool for assessing pupils' scientific literacy.

3.4. Data Analysis

The data analysis used SPSS version 23 (SPSS Inc., Chicago, IL, USA). Descriptive statistics, such as mean, standard deviation, max, and min values, and percentages, were computed to delineate the sample's demographic characteristics. A t-test was employed to discern any statistical differences in mean values achieved by pupils by considering both gender and grade level. The significance stage established for this study was set at 0.05.

4. Results

This study elucidates the outputs derived from statistical student performance measurements in a written laboratory report. Reports representing different grade levels were evaluated, and the SLT instrument was used to delineate the SLT profiles of 629 primary education pupils.

4.1. Analyzing the SLT Stage of Primary Education Pupils

The SLT stage was analyzed by pupils identifying all components of scientific literacy. The percentage of SLT for class 4 and 5 primary education pupils is presented in Table 2. Every student who participated in this survey achieved a mastery stage of only 42.12% in SLT. Among the three subscales investigated in this study, the highest score was studied in the "Describe events scientifically" indicator (M=3.75, SD=1.98). In contrast, the lowest score was attained in the "Analyze and design scientific necessity" component (M=3.02, SD=0.96) on a scale of a max score of 5.00.

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Table 2.
Percentage of pupils' SL

Scientific literacy	No.of Item	Mean	SD	Percentage
Describe events scientifically	2	3.75	1.98	51.59
Analyze and design scientific necessary	2	3.02	.96	42.12
Deliver data and proof scientifically	2	3.22	1.45	49.56
All sub-scales	6	9.99	4.39	47,78

4.2. Gaps In Pupils' Scientific Literacy Skill Values Based on Grade Level

About the question, "Is there a disparity in pupils' science literacy abilities based on their grade level?" a notable discrepancy was studied in the mean science literacy skill values among pupils in the 4th class and those in the 5th class by every part statistical significance ($p < 0.05$). As shown in Table 3, the mean score of 5th-class pupils (M= 50.56, SD= 12.07) exceeded that of 4th-class pupils (M=44.8, SD=9.56) by a margin of 5.76 points.

Table 3.
Gaps in pupils' scientific literacy skill values based on grade level.

Scientific literacy	Variable	N	Mean	SD	p
Describe events scientifically	4th class	319	17.45	3.75	.001
	5th class	310	18.24	4.55	
Analyze and design scientific necessary	4th class	319	14.25	2.87	.001
	5th class	310	15.02	3.42	
Deliver data and proof scientifically	4th class	319	16.10	3.02	.001
	5th class	310	17.30	4.10	
Total	4th class	319	44.8	9.64	.001
	5th class	310	50.56	12,07	

4.3. Gaps In Pupils' Scientific Literacy Skill Values Based on Gender

There is a gap among the mean values of scientific literacy abilities fulfilled by female and male pupils in every part ($p<0.05$). In every part (see Table 4), the mean score of female pupils (M = 51.74 SD = 13.33) was 5.93 points higher than that of male pupils (M=45.81 SD=9.87).

Table 4.
Gaps in pupils' scientific literacy skill values based on gender.

Scientific literacy	Variable	N	Mean	SD	p
Describe events scientifically	Male	228	16.32	3.98	0.000
	Female	401	18.88	5.03	
Analyze and design scientific necessity	Male	228	14.25	2.87	0.000
	Female	401	15.71	3.42	
Deliver data and proof scientifically	Male	228	15.14	3.02	0.000
	Female	401	17.15	4.68	
Total	Male	228	45.81	9.87	0.000
	Female	401	51.74	13.13	

5. Discussion

This study assesses pupils' scientific literacy abilities by considering gender and grade level. The outputs of the two assessment tools show that, on the whole, the mean score for pupils' scientific literacy abilities is 48.75%. Observation results show that the low LS of primary education pupils occurs because they are not used to working on questions like this. It was also found that educators did not teach strategies to pupils to help increase good scientific literacy abilities [3, 8, 15, 16, 33]. Educators also have difficulty implementing effective teaching models to increase scientific literacy and do not yet connect it to pupils' daily lives [4]. Even the scientific literacy abilities of prospective educators are still

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lacking [59] which causes low scientific literacy abilities [60]. These results show that student performance needs to be improved.

Several previous studies also fulfilled similar results [14, 33, 50, 61] showing that the student has a skill stage with poor scientific literacy. In other studies, Udompong and Wongwanich [29] scientific literacy abilities were moderate. Meanwhile, Nursalim, et al. [3] and Yuliana, et al. [8] also reported that pupils had low performance in evaluation and design scientific necessity abilities. A suggested course of action to increase their low scientific literacy stages is to implement discovery studying activities that align with events in their immediate environment [2, 49-51, 62, 63]. The results of this study are handled by Suwono, et al. [2]; Bartels and Lederman [37]; Aiman and Hasyda [50]; Wenning [63] and Balım [64] believing that abilities of scientific literacy can be improved by applying a necessary approach.

This study proved that pupils' Analysis and Design scientific necessity abilities had the lowest score (42.12%), while the Describe events scientifically skill scored the highest (51.59%). Judging by the pupils' written results, most pupils experienced difficulty in analyzing and framing scientific inquiries. Likewise, Nursalim, et al. [3]; Yuliana, et al. [8]; Cavagnetto [26] and Afriana, et al. [65] summarized that the skill of describing scientific events is better than other abilities. Handled by Sholahuddin, et al. [42] assessing the competency to describe events scientifically at around 50%, the competency to deliver data and proof scientifically at 30%, and the competency to design and analyze scientific study at 20%. Additionally, [66] reported that abilities seen as complex were related to analyzing and framing scientific investigations.

When the data was examined by gender, substantial disparities in scientific literacy abilities became apparent. Generally, female pupils achieved the highest and lowest values in the skills related to "describing events scientifically" and "analyzing and framing scientific necessity." Similarly, male pupils fulfill their highest and lowest values in these abilities. These outputs suggest that, on the mean, female pupils exhibit higher values in all sub-abilities. Nevertheless, it is worth noting that this observation contradicts previous study outputs that reported no disparities in science accomplishments among males and females. Else-Quest, et al. [67] for the US, Acar [68] for Turkey, and Gilleece, et al. [69] for Ireland. It is handled by Weaver and Raptis [70] which states that although male pupils tend to receive higher classes, there is no statistical difference in pupils' classes based on gender. The variations in the outputs of this study might be attributed to the ongoing rapid progress in women's emancipation [71]. The outputs of this study also demonstrate that the stereotype and social convention asserting that "men are more proficient than women" in the field of science is gradually eroding.

In recent decades, the effect of gender on pupils' scientific literacy abilities has garnered attention from scholars. A study by Sahin and Ates [18] in Turkey involving 823 individuals revealed that gender accounted for 64% of the variance in science literacy values among women and 48% in science literacy values among men. Bacanak and Gökdere [4]; Cheema [9]; Genc [15]; Kristyasari, et al. [16]; Pramuda, et al. [17] and Mukti, et al. [72] also found similar results to this study. Conversely, Cheema [9] documented that among the entire set of science questions incorporated in the assessment, 49% of the questions were preferred by males, while only 35% appealed to females. Moreover, Louis and Mistele [73] utilized an analysis of a sample comprising 7,377 eighth-class pupils by 239 educations as part of the Trends in International Mathematics and Science Study (TIMSS), revealing a gender Accomplishment gap favoring males in science courses [17].

To comprehend the origins of the gender disparity in literacy, education experts tried identifying the underlying factors using diverse contexts and designs. Specific literature suggests that this gender gap might stem from individual pupils' cognitive traits and attitudes, including intelligence, interests, and self-concept, among others [74, 75]. Conversely, alternative scholarly works center on socially-oriented perspectives, conceiving gender as a social structure or system. Social elements, such as unconscious gender-stereotypical beliefs formed by the social milieu [76] the localized influence of pupils' communities [77] and gender-related disparities in educational institutions [78, 79] might contribute to enduring gender disparities in science accomplishment. The 2022 PISA report [60] further substantiates the argument, asserting that gender disparities in science performance in the PISA assessment exhibit variability. In increased nations, the gender gap is attributed not to inherent talent disparities but to familial or societal influences.

This study revealed a disparity in the scientific literacy skill values achieved by fourth- and fifth-class primary education pupils. Fifth-class pupils attained the highest and lowest values in the abilities related to "Describing events scientifically" and "Analyzing and framing scientific necessity." In contrast, fourth-class pupils fulfilled their highest and lowest values in the same abilities of "Describing events scientifically" and "Analyzing and framing scientific necessity." Likewise, Özdem, et al. [22] also found similar results in his study. According to the data analysis performed in this study, which encompassed 946 primary education pupils, eighth-class pupils exhibited a disparity in their scientific literacy stages compared to sixth- and seventh-class pupils. This divergence can be attributed to the alterations introduced in the new science and technology curriculum in Türkiye. Align with Altun-Yalçln, et al. [20] that the mean scientific literacy score of first, second, third, and fourth-year pupils is 39.15, 39.72, 39.92, and 41.69, it can be summarized that the stage of scientific literacy at the fourth stage is very high.

According to the data analyzed in this study, fifth-class pupils demonstrate a higher stage of proficiency in scientific literacy abilities than fourth-class pupils. This phenomenon is attributed to fifth-class pupils having previously studied several science courses, resulting in more significant experience and comprehension. This discovery contradicts the outputs of You, et al. [79] whose study shows no substantial disparities in scientific literacy among primary education pupils based on their grade levels. In studies involving same-age comparisons, the consideration of grade levels is frequently essential [22, 48, 79, 80] as the assignment of grade levels for a specific age group might encompass factors such as the absence of specific class for gifted or talented pupils or student retention.

Following the outputs presented, Tsoumanis, et al. [61] in their study involving 787 participants, comprising 362 pre-service educators and 425 primary education pupils, summarized that the scientific literacy stage of pre-service educators is superior to that of pupils. Furthermore, Kaehler, et al. [78] utilized a longitudinal study by the German National Education Panel, which involved 2,937 children from kindergarten to the third primary education class. Their results showed that the scientific literacy of kindergarten children increased progressively over time, by variations already apparent in kindergarten. In this study, fifth-class pupils achieved comparatively higher values, which might be linked to their good-increased cognitive abilities. Additionally, studies by Bauer and Booth [25] and Smith, et al. [28] revealed a positive correlation between pupils' cognitive development and scientific literacy abilities in conjunction with their attitudes toward science.

The outputs of this study imply that education in primary education must design specific studying environments that encourage pupils' stages of scientific literacy. It aligns with Boujaoude [81] that teaching, assessment, the quality of textbooks used, participation in extracurricular scientific activities, and science experiences in contexts outside of education are important factors that influence pupils' scientific literacy stages. Therefore, educators must not simply transfer studying through traditional studying methods. The implication is that studying inequality does not emphasize complex events and involves investigation. As emphasized by Yuliana, et al. [8]; Wen, et al. [62] and Afriana, et al. [65] exploring an environment that focuses on hands-on practice is necessary to improve pupils' scientific literacy abilities in a way that is better than traditional lectures. Based on these outputs, educators must focus more on improving scientific literacy abilities.

Based on the outputs of this study, educators should offer pupils substantial guidance and support in conducting hands-on investigations that introduce them to natural events in their immediate environment to enhance their comprehension of scientific literacy (SL). Additionally, pupils should be encouraged to acquire knowledge on these matters and subsequently connect in critical and responsible problem-solving based on scientific information when addressing social implications [82-84]. Further study in this field remains essential, particularly in assessing the effect of experiment-based teaching on pupils' scientific literacy abilities, considering factors such as education type, education stage, gender, and pupils' grade levels.

6. Conclusion

The study outputs show that primary education pupils' mean stage of scientific literacy abilities is comparatively low. Furthermore, this study identified a notable disparity in scientific literacy values based on gender, with female pupils outperforming their male counterparts. Equally important to note is that the stereotype and societal convention asserting that men are superior to women cannot be broadly applied. When examining grade levels, there is a notable disparity among fourth- and fifth-class pupils, with the former achieving higher values in scientific literacy abilities than the latter.

Educators should assess pupils' scientific literacy abilities to plan their teaching strategically. It can assist in enhancing the scientific literacy of primary education pupils by crafting instructional activities that align with contemporary events. In essence, educators should employ effective teaching models to elevate the scientific literacy of primary education pupils. Various studying models encompass necessity-based approaches, problem-based studying, discovery studying, project-based studying, and other science-related direct studying methods. Consequently, pupils should be given more demanding tasks like study-based activities to tackle diverse and intricate events. Future studies should include more participants from different educational backgrounds and fields to understand better and explore scientific literacy.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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