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ASSESSING SCIENTIFIC LITERACY OF COLLEGE STUDENTS WITH TOSLS (TEST OF SCIENTIFIC LITERACY SKILLS)

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Abstract

This study aims to identify the scientific literacy skills of students at Malang State University based on gender, year of study, and study program. The research method uses quantitative description. The sampling technique uses purposive random sampling. The population of the study is S1 students at Universitas Negeri Malang who are pursuing education programs. The sample consists of 208 students, divided into 62 males and 146 females. The data collected includes the results of scientific literacy tests using the TOSLS (Test of Scientific Literacy Skills) instrument and demographic data from the respondents obtained through questionnaires. The test instrument is divided into nine indicators of scientific literacy, including the ability to identify scientific concepts, evaluate the validity of sources, and interpret graphs. Data analysis was conducted using the KR20 reliability test, Shapiro-Wilk normality test, and non-parametric analysis such as Mann-Whitney and Kruskal-Wallis. The results of the study showed that the average level of success in questions was 73.37%, based on gender, with details of male respondents with a score of 74.38% and female respondents with a score of 72.36%. The level of scientific literacy of students based on the year of study in working on questions decreased from the first year to the third year (first year = 37%; second year = 46%; third year = 17%). There was a difference in the level of success in completing questions statistically based on the study program, which showed significance ($H = 47.93$; $p < 0.05$). Geography education students' scores in solving test questions were second worst compared to students studying Biology, Physics, and Chemistry, so they had to do more science-based activities in each lecture activity.

Keywords Identification; science literacy; TOSLS.

INTRODUCTION

Scientific literacy, according to PISA, is the ability to apply knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw conclusions based on scientific evidence (OECD, 2023). PISA's assessment of scientific literacy includes scientific understanding, aspects of the scientific process, and the ability to apply knowledge in real-world situations. The term "scientific literacy" was first coined in the 1950s by Paul DeHart Hurd to refer to the understanding and application of science in society (Rudolph, 2024; Turgut, 2007).

Literature on scientific literacy issues mentions two terms, "science literacy" and "scientific literacy." Science literacy is not the same as scientific literacy, but the two are interconnected (Roberts & Bybee, 2014). Science literacy encompasses literacy practices such as reading, writing, and speaking to understand and communicate scientific knowledge. Scientific literacy is concerned with the understanding of scientific concepts and the ability to apply them in a variety of situations, including non-scientific ones (Narut & Supardi, 2019; Osborne, 2023).

The concept of science literacy encompasses the understanding of basic concepts, the nature of science, and the ability to critically evaluate scientific information. In addition, science literacy involves the use of scientific knowledge for ethical decision-making, critical thinking, and understanding the impact of science and technology on society (Agustina & Rahmawati, 2021; Choi et al., 2011).

Shen (1975) categorized geography-related scientific literacy into three distinct categories: practical, civic, and cultural scientific literacy. Geography plays a pivotal role in fostering the knowledge, competencies, and skills necessary for observing, evaluating, and interpreting information about countries, regions, and the social activities of their inhabitants (Svobodová, 2019; Utami & Zain, 2018). Geography assumes a crucial role by considering multidisciplinary correlations and analyzing phenomena from cultural, political, ethical, religious, and historical perspectives. Geography also emphasizes that scientific theories are not permanent and that scientific evidence can be influenced by interpretation (Allchin, 2014).

Assessing scientific literacy has become crucial to evaluate the extent to which students can utilize scientific knowledge in their daily lives and in academic contexts (Pratiwi et al., 2019), particularly amidst the shifting global education paradigm that increasingly emphasizes critical and analytical thinking skills. Social constructivist theory, as propounded by Vygotsky (1978), highlights the significance of social interaction and collaborative learning in fostering scientific understanding.

In the context of scientific literacy, this theory underscores the need for interactive learning to cultivate critical thinking skills in relation to scientific information (Mtsi & Mabel-wendy, 2021; Soysal, 2020).

Previous research has demonstrated significant variations in science literacy levels among university students. For instance, a study conducted by Johnson et al. (2018) revealed that students often face challenges in applying scientific knowledge to real-world contexts despite possessing adequate theoretical understanding. These findings underscore the need for more integrated and contextualized learning approaches to enhance students' science literacy (Johnson et al., 2020).

Another study by Russell et al. (2023) identified that the utilization of TOSLS (Test of Scientific Literacy Skills) can provide a clear picture of students' abilities in comprehending fundamental scientific concepts such as research methodology, data evaluation, and result interpretation. This study highlights the significance of employing valid and reliable assessment tools in evaluating comprehensive science literacy at the academic level (Russell & Martin, 2023). Furthermore, a comparative analysis conducted by Valladares (2021) underscored the existence of significant disparities in science literacy among students from diverse academic disciplines. The findings of this study shed light on the contextual factors that influence the development of science literacy and emphasize the importance of personalized and adaptive educational approaches (Valladares, 2021).

Another study conducted by Sutiani et al. (2021) demonstrated that the implementation of a curriculum focused on developing critical thinking skills in the context of science can significantly enhance students' science literacy. These findings underscore the need for a holistic and sustainable learning approach to address the challenges of science literacy in the current era of global education (Sutiani et al., 2021). A meta-analysis study by Pacaci et al. (2023) evaluated the effectiveness of various instructional strategies in improving science literacy among university students. The results of this analysis provide empirical evidence regarding the most effective approaches for fostering science literacy understanding and skills across diverse educational settings (Pacaci et al., 2023). Research by Aristeidou et al. (2023) emphasizes the significance of technology integration in instructional approaches to enhance science literacy. This study suggests that utilizing digital platforms and online learning tools can facilitate more interactive and immersive learning experiences for comprehending complex scientific concepts (Aristeidou & Herodotou, 2020).

Scientific literacy has become a crucial aspect of higher education development, particularly at Universitas Negeri Malang, a center of education that influences the understanding and application of scientific knowledge across various disciplines. Studying science literacy among students at this institution is essential, considering the global challenges posed by complex changes that require strong analytical and reasoning skills in dealing with scientific information. Based on these facts, science literacy among Universitas Negeri Malang students exhibits significant variations, with a majority of students facing difficulties in integrating scientific knowledge in practical and critical contexts. Despite having a strong theoretical foundation in various disciplines, their science literacy remains suboptimal in meeting the demands of scientific and technological advancements. This aligns with findings that a lack of hands-on research and scientific exploration experiences is a major contributor to low science literacy levels in higher education. This article aims to address the following questions: (1) What is the level of science literacy among students in Geography Education, Biology, Physics, Chemistry, and PGSD? (2) Are there differences in science literacy levels based on the year of study? (3) Are there differences in science literacy levels between male and female students?

METHOD

The objective of this research is to obtain a comprehensive understanding of the science literacy levels among undergraduate students. The hypotheses employed in this study are as follows:

Hypothesis 1:

- Null Hypothesis (Ho1): There is no significant difference in science literacy levels between male and female students.
- Alternative Hypothesis (Ha1): There is a significant difference in science literacy levels between male and female students.

Hypothesis 2:

- Null Hypothesis (Ho2): There is no significant difference in science literacy levels based on students' academic year.
- Alternative Hypothesis (Ha2): There is a significant difference in science literacy levels based on students' academic year.

Hypothesis 3:

- Null Hypothesis (Ho3): There is no significant difference in science literacy levels among students from different study programs.
- Alternative Hypothesis (Ha3): There is a significant difference in science literacy levels among students from different study programs.

The research approach employed in this study is quantitative, adopting a descriptive-comparative design. Descriptive-comparative research is utilized to compare science literacy levels among groups of students based on specific variables such as gender, academic year, and study program. The study was conducted from March to May 2024 at Universitas Negeri Malang.

The population of this study comprised undergraduate students enrolled in education programs at Universitas Negeri Malang. The research sample was determined using purposive sampling, specifically targeting five education study programs related to science literacy: Geography Education, Elementary School Teacher Education, Biology Education, Physics Education, and Chemistry Education. The research sample consisted of 208 students pursuing undergraduate education programs in the Faculty of Social Sciences (FIS), the Faculty of Mathematics and Natural Sciences (FMIPA), and the Faculty of Education (FIP) at Universitas Negeri Malang. Statistical analysis was conducted based on the responses provided by 208 students (62 males and 146 females). The students involved in the study were in their first, second, and third years of the Geography Education, Elementary School Teacher Education, Biology Education, Physics Education, and Chemistry Education undergraduate programs.

Data Collection

The data collected in this study encompasses the results of the science literacy test using the TOSLS (Test of Scientific Literacy Skills) instrument, and the demographic data of respondents obtained through a questionnaire.

1. The primary data source comprises the students who participated in the test and questionnaire. Students were requested to complete the test and questionnaire anonymously and voluntarily within a predetermined timeframe. The test was administered anonymously and on a voluntary basis. Science literacy evaluation was conducted using the TOSLS (Test of Scientific Literacy Skills) (Gormally et al., 2012), which was presented in the form of 28 multiple-choice questions specifically designed for undergraduate students. These items were categorized into nine indicators of science literacy. Students were prohibited from using any aids (e.g., calculators, mobile phones) or accessing external information sources during the test. The collected data

was subsequently processed and analyzed to identify science literacy levels and comparisons between groups.

2. Secondary Data Sources included relevant literature and previous research related to the study topic, encompassing documents and publications on science literacy and educational research methodologies.

The data analysis process began with assessing the reliability of the science literacy test (TOSLS) instrument using the KR20 formula (Retnawati, 2017). Instrument validity was established through evaluation by competent experts aligned with the science literacy indicators, providing constructive feedback. The Shapiro-Wilk test was employed to assess data normality and distribution. Since the results indicated non-normal data distribution ($W = 0.94$; $p < 0.05$), further analysis utilized non-parametric tests. To compare results based on gender, the Mann-Whitney two-sample non-parametric test was employed. For comparisons based on academic year and study program, the Kruskal-Wallis test served as a non-parametric alternative to one-way ANOVA. Duncan's test was implemented as a post-hoc analysis.

Test item analysis was conducted using item discrimination and difficulty indices. The difficulty index reflects the ease or difficulty of an item, while the discrimination index indicates the item's ability to differentiate between students with high and low knowledge levels. Items are considered difficult if the difficulty index falls below 30, and conversely, easy if it exceeds 80. The discrimination index reflects the item's ability to distinguish between student abilities. Items with a negative discrimination index (D) should be excluded. Items with D = 0.0–0.19 are considered poor and require revision; D = 0.2–0.29 are acceptable; D = 0.3–0.39 are good, and $D > 0.4$ indicates very good items (Ebel & Frisbie, 1991).

FINDINGS AND DISCUSSION

Findings

The reliability test in this study yielded a value of 0.79, indicating that the instrument is considered reliable. The minimum score obtained on the test was 8 points, and the maximum score was 28 points. The median score was 21. The overall average score on the test was 20.54 (SD=4.68). The average success rate for the test items was 73.37%, with a breakdown of 74.38% for male respondents and 72.36% for female respondents. The average score for female respondents was 20.23 (SD = 4.43) and for male respondents was 21.27 (SD = 5.18). Statistical analysis using the Mann-

Whitney test (W = 3706.5; $p = 0.038$) revealed a significant difference in test item success rates between male and female respondents. This result indicates that the observed difference in performance is not due to chance and is statistically significant.

Table 1. Descriptive test characteristics

Number of respondents	208
Mean score	20,54
Standard deviation	4,68
Co. varian	22,78%
Median	21
Modus	24
Minimum	8
Maximum	28
Extent of variaton	20

This study also investigated science literacy levels among students based on their academic year. The analysis of responses provided by the participants revealed a decreasing trend in the percentage of correct answers from the first to the third year (first year = 37%; second year = 46%; third year = 17%). However, statistical analysis using the Kruskal-Wallis test did not indicate a significant difference in test performance across academic years (H = 3.72; $p = 0.156$).

Table 2. Success Rate Based on Study Program

Study Program	Number of Respondents	Mean Score	Standard Deviation	Success Rate (%)
PGSD	40	16,05	4,12	57,3
Biology	74	22	4,10	78,6
Physics	15	21,87	4,53	78,1
Chemistry	63	21,78	4,94	77,8
Geography	16	18,94	4,22	67,6

The analysis of science literacy based on study programs revealed that Biology Education students achieved the highest success rate on the test items, while Elementary School Teacher Education (PGSD) students had the lowest success rate (Table 2). This observed difference in test performance across study programs was statistically significant (H = 47.93; $p < 0.05$). Based on the statistical analysis, geography education students performed worse on the test than biology, physics, and chemistry education students.

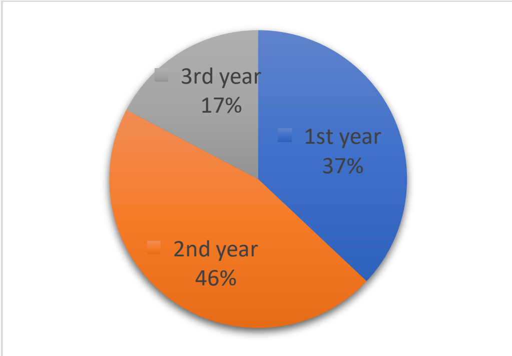

Figure 1. Percentage of Respondents by Academic Year

Figure 1 illustrates the distribution of respondents based on their academic year. First-year students constitute 37% of the respondents, second-year students comprise 46%, and third-year students make up 17%. This indicates that second-year students form the largest group, while third-year students are the smallest. The distribution of respondents is crucial as it can influence research outcomes and introduce bias. The majority of respondents being from the second year may provide a stronger perspective on their performance compared to first-year and third-year students.

Table 2 presents the mean scores and success rates of students by study program. Elementary School Teacher Education (PGSD) has the lowest score (16.05) with a success rate of 57.3%, while Biology Education has the highest (22.00) with a success rate of 78.6%. Physics, Chemistry, and Geography Education have average scores of 21.87 (78.1%), 21.78 (77.8%), and 18.94 (67.6%), respectively. The results demonstrate significant variations in test performance across study programs. Biology Education exhibits the highest success rate, while PGSD has the lowest, with this significant difference potentially influenced by factors such as curriculum, teaching methods, or students' basic abilities.

The information provided in Table 2 and Figure 1 sheds light on the distribution of respondents based on the academic year and study program, as well as their success rates in completing the test items. This information can be utilized to identify areas that require further attention in terms of curriculum or teaching methods to enhance student learning outcomes.

Item Analysis

Item analysis was conducted to determine the difficulty index and discrimination index of each question item. The results of the item analysis indicate that the difficulty index of the question items ranges from 36.06 to 90.87, which is considered acceptable. The average difficulty index for the entire test is 73.37. The average discrimination index for the test items is 0.41. The discrimination index of each individual item ranges from 0.05 to 0.66. Three test items (items 10, 23, and 26) exhibit a discrimination index lower than 0.2.

Frequency analysis of answers reveals that item number 10 has the highest error rate and the lowest success rate (I = 36.06). This item assesses the ability to evaluate the credibility of literary sources, including assessing the author's expertise and the purpose of the website. Despite the website's clear promotion of a specific product and its unreliability, many students chose distractors as the correct answer.

Table 3. Frequency of Responses for Science Literacy Test (TOSLS) Items

Competency	Test Item	Number of Responses				Success Rate Per Item %	Average Success Rate
		a	b	c	d		
1	1	18	167	7	16	80,29	80,61
	8	6	10	36	156	75,00	
	11	3	180	4	21	86,54	
2	10	78	75	47	8	36,06	69,04
	12	8	63	130	7	62,50	
	17	18	152	18	20	73,08	
	22	19	1	178	10	85,58	
	26	8	13	183	4	87,98	
3	5	6	23	25	154	74,04	81,09
	9	12	163	13	20	78,37	
	27	7	189	5	7	90,87	
4	4	19	19	153	17	73,56	66,23
	13	19	71	25	93	44,71	
	14	7	28	148	25	71,15	
	25	9	157	17	25	75,48	
5	15	13	11	33	151	72,60	72,60
6	2	15	19	160	14	76,92	73,20
	6	12	26	132	38	63,46	
	7	173	17	3	15	83,17	
	18	144	48	7	9	69,23	
7	16	0	165	30	13	79,33	72,60
	20	76	119	7	6	57,21	
	23	3	5	31	169	81,25	
8	3	25	136	45	2	65,38	75,00
	19	6	21	175	6	84,13	
	24	6	9	36	157	75,48	
9	21	7	8	170	23	81,73	75,48
	28	13	144	10	41	69,23	

Table 3 presents the frequency of responses given by students to each test item on the Science Literacy Test (TOSLS) and the average success rate for each item. The presentation of data in this table aims to provide a clear picture of the extent to which students are able to answer the given questions correctly and the competencies assessed by each test item.

The "Competency" column indicates the competency assessed by each test item, with the item numbers listed in the "Test Item" column. The "Number of Responses" column displays the distribution of student responses for options A, B, C, and D, identifying effective distractors. The "Success Rate per Item" column shows the percentage of correct answers, helping to identify the easiest or most difficult test items. The average success rate in the last row indicates the overall success for each competency group.

Table 3 aims to identify test items that require improvement based on difficulty level and distractor effectiveness. For instance, item number 10 has a low success rate (36.06%), indicating students' difficulty in assessing the credibility of information sources. This result provides measurable feedback for instructors to revise the test and guide students to be more critical in evaluating information sources.

The analysis results suggest that students struggle with assessing the credibility of information sources, possibly due to a lack of motivation for critical evaluation when using sources for assignments, projects, or essays. According to Gormally et al. (2012), the internet has changed the way information is accessed, reducing the need for critical evaluation. Therefore, guidance on critical evaluation of information sources, especially those from the internet, is necessary at all levels of education.

Science Literacy Analysis

Science literacy encompasses nine indicators within two aspects of literacy: (1) understanding the scientific method and (2) managing, analyzing, and interpreting scientific data. The nine indicators of science literacy include (a) Identifying valid scientific ideas, (b) Evaluating the validity of literature sources, (c) Evaluating the use and misuse of scientific information, (d) Understanding the elements of research methods and their impact on scientific findings, (e) Identifying graphs and describing data, (f) Reading and interpreting graphs representing data, (g) Solving problems using quantitative skills, including probability and statistics, (h) Understanding and interpreting basic statistics, and (i) Justifying conclusions, predictions, and inferences based on quantitative data (Gormally et al., 2012).

Table 4. Results of Statistical Analysis by Study Program

No	Indicators		Geography Education	Elementary School Teacher Education	Biology Education	Physics Education	Chemistry Education
1	Identify a valid scientific argument	I (%)	77,08	61,67	84,69	84,45	87,50
		M	2,31	1,85	2,54	2,53	2,63
		SD	0,79	1,05	0,74	0,74	0,70
		H			21,13		
		p			0*		
2	Evaluate a credible literature source	I (%)	60,00	56,00	74,87	72,00	72,06
		M	3,0	2,8	3,74	3,60	3,60
		SD	0,97	1,02	0,89	1,06	1,01
		H			26,62		
		p			0*		
3	Evaluate proper and improper use of scientific information	I (%)	75,00	72,50	84,23	88,89	82,54
		M	2,25	2,18	2,53	2,67	2,48
		SD	0,77	0,84	0,67	0,62	0,72
		H			8,67		
		p			0,07		
4	Understand elements of research design and determine their impact on scientific research results and conclusions	I (%)	60,94	46,25	71,28	78,33	71,43
		M	2,44	1,85	2,85	3,13	2,86
		SD	0,96	0,86	0,92	0,99	1,08
		H			34,04		
		p			0*		
5	Create an appropriate graph from the data	I (%)	56,25	40,00	78,38	80,00	88,89
		M	0,56	0,40	0,78	0,80	0,89
		SD	0,51	0,50	0,41	0,41	0,32
		H			33,41		
		p			0*		
6	Read and interpret graphical representations of data	I (%)	64,06	68,13	78,04	75,00	72,62
		M	2,56	2,73	3,12	3,00	2,90
		SD	1,21	1,18	0,94	1,00	1,00
		H			5,10		
		p			0,28		
7	solve problems using quantitative skills, including basic statistics	I (%)	81,25	60,83	76,12	75,55	73,02
		M	2,44	1,83	2,28	2,27	2,19
		SD	0,63	1,13	0,84	0,80	0,82
		H			5,58		
		p			0,23		
8	Understand and interpret basic statistics	I (%)	62,50*	41,67	84,68	80,00	86,77
		M	1,86	1,25	2,54	2,40	2,60
		SD	0,89	0,90	0,71	0,91	0,64
		H			64,82		
		p			0*		
9	Justify inferences, predictions, and conclusions based on quantitative data	I (%)	75,00	58,75	80,41	73,34	80,96
		M	1,50	1,18	1,61	1,47	1,62
		SD	0,73	0,68	0,64	0,74	0,52
		H			15,20		

p	0*

Legend: I – success rate, M – median, SD – standard deviation, H – nilai Kruskal–Wallis test. *p < 0.05 - statistically significant difference

Analysis of individual competencies based on the study program reveals that PGSD (Elementary School Teacher Education) students have the lowest success rates across all tested skills (Table 4). Geography students recorded the second-worst results in nearly all competencies, except for competency 7 (quantitative problem-solving), although these differences were not statistically significant. The competency with the lowest success rate was competency 6 (reading and interpreting graphs). However, this was also not statistically significant. Significant differences were found in five competencies: 1, 2, 4, 8, and 9. Competency 1 (identifying scientific arguments) showed that Geography students achieved a success rate of 77.08%, with students from single-study programs (Biology, Physics, Chemistry, Geography) performing better in this competency compared to PGSD students.

In the second competency, evaluating credible literature sources, Geography students achieved an average success rate of 60%. Duncan's test revealed that Biology, Physics, and Chemistry students performed significantly better than Geography and Elementary School Teacher Education students. Regarding competency four, understanding research methods, Elementary School Teacher Education students demonstrated the lowest performance (46.25%), followed by Geography students (60.94%). Duncan's test confirmed that Physics, Biology, Chemistry, and Geography students outperformed Elementary School Teacher Education students, with Geography students also performing significantly worse than Physics students. In competency five, identifying graphs and describing data, Geography students exhibited the lowest performance (56.25%), while Chemistry students achieved the highest (88.89%). Duncan's test indicated that Physics, Biology, and Chemistry students significantly outperformed Geography and Elementary School Teacher Education students.

In competency eight (understanding and interpreting basic statistics), Elementary School Teacher Education students demonstrated the lowest performance (I = 41.67%), followed by Geography students (I = 62.5%). Duncan's test revealed that Physics, Biology, Chemistry, and Geography students possessed superior statistical knowledge compared to Elementary School Teacher Education students. Additionally, Biology, Biochemistry, and Chemistry students outperformed Geography students in the domain of basic statistics. Interestingly, while Geography students exhibited adequate mathematical skills for problem-solving, they struggled to grasp the significance of statistics in research.

Competency Nine assessed students' ability to justify predictions, conclusions, and scientific inferences based on quantitative data. From an academic discipline perspective, the lowest success rate, with a score of 58.75%, was achieved by Elementary School Teacher Education students. Geography education students attained a relatively better success rate of 75%. Duncan's test confirmed that Biology and Chemistry education students demonstrated superior proficiency in justifying scientific predictions, conclusions, and inferences based on quantitative data compared to Elementary School Teacher Education students.

Analysis of Science Literacy Skills Based on Categories A and B

Science literacy skills are categorized into two primary domains: (A) competencies related to identifying and analyzing inquiry methods that lead to scientific knowledge (competencies 1-4) and (B) competencies pertaining to organizing, analyzing, and interpreting quantitative data and scientific information (competencies 5-9). category A, the maximum score is 15 points. The success rate for completing the tasks in this category was 73.01%, and the average score was 10.95 (SD = 2.61). For female respondents, the average score was 10.95 (SD = 2.59), and for male respondents, it was 10.97 (SD = 2.68). Employing the Mann-Whitney U test, no statistically significant differences were observed in terms of gender, particularly in completing tasks focused on identifying and analyzing inquiry methods (W = 4428; pA = 0.804). In category B, with a maximum score of 13, respondents achieved a success rate of 73.78% and an average score of 9.59 (SD = 2.67). For female respondents, the average score was 9.29 (SD = 2.46), and for male respondents, it was 10.31 (SD=2.99). Statistical analysis using the Mann-Whitney U test revealed statistical significance based on the observed difference (W = 3247; pB = 0.001).

Table 5. Results of Statistical Analysis of Science Literacy Categories Based on Year of Study and Study Program

Year	**Understand Methods of Inquiry Leading to Scientific Information**					**Organise, Analyze, and Interpret Quantitative Data, and Scientific Information**				
	I (%)	*M*	*SD*	*H*	*p-value*	I (%)	*M*	*SD*	*H*	*p-value*
1st	75,32	11,30	2,22	1,432	0,489	75,02	9,75	2,44	8,854	0,012*
2nd	72,35	10,85	2,61			76,36	9,93	2,64		
3rd	69,91	10,47	3,28			64,32	8,36	2,89		
Study Program										

Geography	66,67	10,0	2,00	41,846	0*	68,75	8,94	3,07	35,845	0*
PGSD	57,83	8,68	2,41			56,73	7,38	2,41		
Biology	77,75	11,66	2,20			79,52	10,34	2,38		
Physics	79,56	11,93	2,37			76,41	9,93	2,74		
Chemistry	77,14	11,57	2,51			78,51	10,21	2,24		

Legend: I – success rate, M – median, SD – standard deviation, H – value of Kruskal–Wallis test. *$p < 0.05$ - statistically significant difference

The average score for completing tasks focused on identifying and analyzing inquiry methods (category A) decreased from year one to year three (Table 5). However, statistical analysis using the Kruskal-Wallis test did not reveal a statistically significant difference in performance across study years. A notable difference emerged in category B. In this category, we observed the lowest average score again among students in the third year of study (Table 5). Duncan's test indicated that third-year students completed the assigned tasks with significantly poorer results than first- and second-year students. An analysis of the factors contributing to the low success rates of student responses is a limitation of this study. These findings will be pursued in future research focused on identifying the causes of low science literacy levels among students based on their year of study.

Elementary School Teacher Education students obtained the lowest average scores in both categories tested. Kruskal-Wallis test results showed statistically significant differences. In category A, Geography students scored significantly lower than Biology, Physics, and Chemistry students. PGSD students also statistically had lower average scores than students from other single-discipline study programs.

In category B, the statistical analysis revealed that the average scores of elementary school teacher education students were significantly lower than those of geography, biology, physics, and chemistry students. These results suggest that Elementary School Teacher Education students possess weaker competencies and skills in critically evaluating scientific experiments, data, and evidence-based conclusions, reflecting the low level of science literacy among prospective teachers.

Discussion

The findings of this study demonstrate that the TOSLS instrument meets the required criteria and can be effectively employed at Universitas Negeri Malang for the comprehensive and continuous evaluation of students' science literacy. This aligns with the findings of Rahmawati's (2021) research, which established the efficacy of TOSLS for science literacy assessment. These outcomes corroborate science literacy theories that emphasize the significance of science literacy skills in addressing global challenges (Rahmawati et al., 2022). Additionally, Gormally's (2012) study highlights the effectiveness of TOSLS in measuring students' abilities to evaluate scientific information and arguments. The instrument can effectively assess students' proficiency in identifying valid scientific arguments and conducting critical evaluations of scientific information (Gormally et al., 2012).

The participants in this study completed the test with a success rate of 73%. The success rates for identifying inquiry methods and analyzing quantitative data were relatively similar. Competencies with success rates below 70% included evaluating the credibility of scientific information sources and understanding research design. Competencies with success rates above 80% included identifying valid scientific arguments and critically evaluating the use of scientific information. Geography students achieved a success rate of 66.67%, while PGSD students achieved only 57.83%, both of which are considered unsatisfactory.

Among geography education students, findings indicate issues in five competencies, with success rates ranging from 56.25% to 64.06%. The lowest success rate was observed in questions related to competencies focused on determining the correct graph representing the data. Students were asked to choose the correct bar graph according to the data. This indicates that students are not familiar with statistical graphs or are unable to construct graphs when completing a task. Low success rates were also achieved in competencies related to reading and interpreting data represented in graphical form, indicating that geography education students lack adequate competencies and skills related to the use of graphs. Based on the results of the TOSLS (Test of Scientific Literacy Skills), it is known that geography education students who have taken courses related to statistical data processing methods, analysis, evaluation, and data presentation do not have sufficient competencies. Therefore, it is crucial to develop students' competencies in creating and interpreting graphs and diagrams through exercises and assignments.

The low science literacy skills of geography students in constructing and interpreting graphs indicate a lack of practical experience with statistical tools. Interactive and experiential learning approaches can help address this weakness. Constructivist theories, such as those proposed by Vygotsky, assert that learning is an active process in which students construct new knowledge through experience and social interaction (Habsy et al., 2024). The low performance in graph-related competencies suggests that this cognitive process may not be fully developed in geography education students. This is related to the theory of information processing capabilities. According to this theory, understanding statistics and graphs requires complex cognitive abilities, including the capacity to encode, store, and retrieve numerical and visual information (S.-H. Wang, 2021). When students work on science literacy questions involving graphs, they must process visual and textual information simultaneously. This requires significant working memory resources (Kim et al., 2021). If the information to be processed is too complex or poorly structured, working memory can become overwhelmed, causing students to struggle with understanding and analyzing graphs.

Issues were also found in the competencies of understanding and interpreting basic statistics, despite students also studying several courses on statistics within their geography curriculum. The highest success rate was observed in competencies focused on problem-solving by applying quantitative analysis, particularly percentage calculations (An & Zhang, 2024; Chuang & Chang, 2024; Kusakli & Sönmez, 2024; X. Wang et al., 2022). Students have only acquired basic mathematical knowledge and skills. Unsatisfactory success rates (around 60%) were also found in critical assessment skills regarding the credibility of literature sources and determining the impact of research design elements on results and conclusions.

The difficulties faced by geography education students in understanding and interpreting basic statistics can be explained through the theory of meaningful learning. Meaningful learning occurs when new information is connected to pre-existing knowledge and experiences (Sexton, 2020). In this context, students with a strong understanding of fundamental mathematical concepts will find it easier to comprehend and interpret statistics (Christidis et al., 2024; Dani & Al Quraan, 2023; Siems-Muntoni et al., 2024). Students with a solid grasp of basic mathematical and statistical concepts can more easily connect and recall new information, whereas those with weaker understanding will struggle to grasp statistical information in scientific literacy questions (Ke et al., 2021; Öztürk et al., 2020). This is because they lack sufficient knowledge to link new information with their existing knowledge, making the new information less meaningful and harder to remember.

The low level of scientific literacy among geography education students is attributed to the lack of research and inquiry activities that train critical thinking skills. Additionally, coursework has not fully integrated the scientific process through problem-solving-focused learning models. Learning models that emphasize problem-solving can help students tackle complex problems (Damayanti, 2022) and can enhance their reasoning, communication, self-reflection, and problem-solving abilities (Akben, 2020; Aslan, 2021). Achieving high scientific literacy among students is a prerequisite for advancing science and technology, which is one of the pillars of a knowledge-based society, and for improving the quality of science education in primary and secondary schools (Chen, 2024; Imjai et al., 2024; Liu et al., 2024).

The low scientific literacy skills among geography students are also due to insufficient exposure to science-based activities in their learning process, necessitating an increase in the frequency of science-based activities in their coursework. Research by Pereira et al., (2020) indicates that a curriculum lacking emphasis on hands-on research and inquiry experiences can limit the development of students' critical and analytical thinking skills. This aligns with findings that students often require more opportunities to apply scientific concepts in practical contexts relevant to their field of study (Windschitl et al., 2020).

Based on the discussion in this study, several recommendations can be made to enhance the scientific literacy of geography education students: 1) Strengthening science-based learning models (Pantiwati, 2023) by developing a curriculum that better integrates science-based activities, such as field research, laboratory work, and problem-based projects, can improve students' ability to practically apply scientific concepts. 2) Problem-solving training, emphasizing the development of problem-solving skills through learning models that focus on scientific processes (Riyanto et al., 2024), can be a strategic step in preparing students to handle complex situations in the field of geography. 3) Increasing Exposure to Scientific Literature by providing more opportunities for students to engage in reading and evaluating relevant scientific literature (Aida et al., 2024) within their field of study can enhance their understanding and critical analysis of scientific sources. 4) Collaboration Between Higher Education and Secondary Schools in developing science education programs (Kahila et al., 2023; Kanngieser et al., 2024; Mokher & Mella-Alcazar, 2024; Widodo, 2021) can help strengthen the foundation of scientific literacy from an early age, particularly in the field of geography.

CONCLUSION

Based on the research findings, it is concluded that there are significant differences in students' scientific literacy skills based on gender, with males having higher average scores compared to females. Although there is a decline in scores from the first to the third year, there are no significant differences based on the year of study. Additionally, there are significant differences based on the study program, with geography education students having the lowest scores compared to students in Biology, Physics, and Chemistry programs. This indicates that gender and study program significantly affect scientific literacy, whereas the year of study does not. The strength of this study lies in its comprehensive statistical analysis and the variety of variables examined. However, its limitations include potential sample bias and the lack of longitudinal data. Suggestions for future research include expanding the sample size and considering other factors that may influence students' scientific literacy.

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