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Science Literacy Skills Among Primary School Teacher Education Students Based on Critical Thinking and Science Process Skills

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With a focus on critical thinking and science process skills in the context of science education, this study aims to assess the science literacy abilities of students enrolled in the Primary School Teacher Education (PGSD) program. 53 PGSD students from Yogyakarta State University were chosen for the study using a complete sample technique, which is quantitative in nature. A subjective test was used in the data collection process. IBM SPSS Statistics 24 was utilized to aid in the data analysis process.. The findings suggest that: 1) Science process skills have a similarly strong positive link with and influence on students' science literacy abilities; and 2) Critical thinking skills are considerably and positively related to and influence students' science literacy abilities. According to the report, science courses in higher education should emphasize developing critical thinking abilities by encouraging mastery of science process skills and making use of appropriate teaching models and methodologies.

Keywords: critical thinking skills, process skills, science learning, scientific literacy

1. Introduction

A combination of abilities, beliefs, attitudes, comprehension, and knowledge regarding the importance of science to individuals are often included in scientific literacy. This combination helps people develop their research and inquiry skills, which encourages a dedication to lifelong learning and continuous intellectual curiosity [1]. Moreover, there exists an alternative viewpoint about science literacy, wherein science literacy refers to the capacity of humans to understand, evaluate, and create judgments using scientific knowledge that has been obtained [2], [3]. In the current fast changing era of information and technology, science literacy has become more and more crucial. This is because individuals are faced with various complex issues and problems that require understanding and decision-making based on accurate and reliable scientific information [4]. As such, fostering science literacy has become a vital component of modern education systems around the world, ensuring that individuals are well-equipped to navigate and contribute to a science-driven society. According to Gurses et al., [1], the definition of science literacy is only relevant to the active utilization of scientific process skills.

Promoting scientific literacy as a central objective in science education has become increasingly significant over time. As highlighted by various sources, scientific literacy is deemed crucial for equipping the current generation to tackle future challenges effectively [5], [6]. Science literacy plays a crucial role in people's daily lives, as emphasized by Turiman et al, [7]. It not only helps individuals make informed decisions but also enables them to engage critically with scientific information presented in everyday contexts, such as news reports, health advice, and environmental issues.

Integrating scientific knowledge and understanding into the daily lives of individuals within a community is a core goal and a key indicator of the effectiveness of science education in any country [8] [9]. The success of science education depends critically on scientific literacy, as these sources highlight. The Indonesian Minister of Education and Culture Regulation No. 58 of 2014, which pertains to the 2013 Curriculum for Junior High School, is a major step in the right direction for Indonesia in accomplishing this aim.

The low level of science literacy among students remains a significant educational challenge in Indonesia [10]. Despite educators recognizing its importance, this does not necessarily translate to well-developed science literacy among students [11]. This is evident in the data on Indonesian students' performance in the PISA science literacy assessments. Across the four assessments conducted in 2006, 2009, 2012, and 2018, the average science literacy score for Indonesian students ranged between 382-395 [12]. This suggests that Indonesian students' science literacy skills remain relatively low compared to the average skills of students from other participating countries. Such statistics underscore the urgency for educational reform and the need to adopt more effective science teaching methodologies that can enhance students' engagement and understanding.

Multiple factors contribute to the limited degree of scientific knowledge among pupils. An important problem is the traditional science education methods that fail to recognize the significance of reading and writing as crucial skills for students in the field of science [13]. Second, Students' ability to interpret graphs and tables presented in questions is often low. Students are accustomed to simply filling in provided tables, limiting their ability to interpret graphs and tables [14], [15]. Third, students are not accustomed to solving science literacy test questions [16], [17]. These traits imply that pupils' acquisition of scientific literacy is significantly influenced by the instructional process in schools. Additionally, educators have a critical role in supporting students' scientific literacy throughout their academic careers [18].

Science learning cannot be limited to the theoretical implantation of concepts [19]. Therefore, students need to engage in scientific processes that prioritize skills while understanding and discovering the content and purpose of the concepts they are learning. In order to advance science literacy, science learning must incorporate science process skills [20]. Science process skills refer to a collection of talents and competencies required to carry out scientific procedures in order to solve problems [21], [22]. Science process skills involve the ability to observe, collect data, formulate hypotheses, design experiments, analyze data, and communicate research findings [1], [23].

The two different categories of scientific process skills are integrated science process skills and fundamental scientific process abilities [7]. The fundamental scientific process abilities encompass the acts of observing, classifying, measuring and utilizing numerical data, making logical deductions, anticipating outcomes, effectively conveying findings, and comprehending geographical and temporal linkages. Integrated science process skills encompass the abilities to analyze data, establish operational definitions, control variables, formulate hypotheses, and carry out experiments [24]–[26]. According to initial research, process skills are considered crucial for the advancement of scientific conceptions and the enhancement of critical thinking abilities [27]–[30].

Scientific critical thinking abilities are becoming more and more important in the present world, which is controlled by scientific and technology breakthroughs. Scientific critical thinking involves systematic, rational, and reflective thinking processes in understanding, analyzing, and evaluating information related to science [31], [32]. Scientific critical thinking skills are intricately connected to the cultivation of science process skills, including observation, hypothesis formulation, experiment design, and data analysis [33], [34]. Scientific critical thinking helps students understand the scientific process in-depth and develop a more comprehensive understanding of scientific concepts [35].

Critical thinking skills can also hone science and process skills in discovering new concepts from learning activities [36], [37]. Forawi [38] also states that critical thinking skills need to be taught in science education. This is in line with Republic of Indonesia's Minister of Education's Regulation No. 41 of 2007, which addresses requirements for basic and secondary education. The regulation highlights the need of developing thinking abilities, especially during the elaboration phase of the learning process. Students who develop scientific critical thinking skills become autonomous thinkers who can successfully handle difficult problems in both scientific and everyday situations. They also learn how to think critically, examine data, and come up with new ideas [39]–[41].

The Programme for International Student Assessment (PISA), one of the measures used to assess students' scientific literacy, consistently shows lower-than-average reading skills among Indonesian pupils [42]. This is evident from Indonesian students' numerical ability scores, which have declined since 2000 and have not significantly improved since then. The numerical proficiency score of Indonesian students in 2000, 371 students participated in the first year of the Programme for International Student Assessment (PISA).

In 2003, it went up to 382. However, in 2006, the score decreased to 393, and in 2009, it slightly increased to 402. Thereafter, there was a continuous decline in 2012 with a score of 396, 395 in 2015 (a decrease of 1 point from the previous year), and the lowest point was in 2018 with a score of 371. The data released by PISA is a reference for assessing the quality of education worldwide, covering assessments of reading, mathematics, and science abilities. These figures clearly show how much worse Indonesia's education system is compared to other Southeast Asian nations with higher ranks than Indonesia, such as Singapore, Malaysia, Brunei Darussalam, and Thailand [42]. The primary objective of the Programme for International

Student Assessment (PISA) is to evaluate the efficacy of a nation's educational system on a global scale. Therefore, PISA employs questions designed to assess pupils' higher order thinking capabilities, or higher order cognitive abilities (HOTS). Critical and creative thinking are prerequisites for answering questions requiring higher order thinking skills (HOTS) from students.

As the education sector rapidly evolves, enhancing science literacy skills among Primary School Teacher Education (PGSD) students has become increasingly important. Science literacy, which involves understanding scientific concepts and processes, is crucial for future teachers who will mentor pupils to become citizens with a scientific literacy. Critical thinking and science process skills are two fundamental aspects of science literacy. Critical thinking allows students to analyze, evaluate, and integrate information, leading to a more profound grasp of scientific principles. Conversely, science process skills—such as observing, hypothesizing, experimenting, and concluding—offer a practical approach to scientific inquiry and problem-solving. This introduction highlights the pivotal importance of critical thinking and science process abilities in enhancing the scientific literacy of PGSD students, enabling them to proficiently impart these essential skills to their prospective pupils.

Given that scientific education equips PGSD students with the necessary abilities for their future responsibilities in primary schools, it is imperative for them to cultivate both critical thinking and science process skills. Teachers are crucial in ensuring educational success, making these skills particularly important. This study stands out from previous research by using a quantitative approach, concentrating on PGSD students as the research subjects, and exploring science literacy through the aspects of critical thinking and science process skills. Consequently, the study is titled "Science Literacy Skills among Primary School Teacher Education Students in Terms of Critical Thinking and Science Process Skills."

2. Methods

In order to investigate the connections and trends between two or more variables, this study takes a quantitative approach [43]. The study involved a sample of 53 students from the Primary School Teacher Education program at Yogyakarta State University. The total sampling technique was employed, meaning the sample size encompasses the entire population of interest [44].

Data were collected using a subjective test method, which relies on personal judgment and interpretation. This type of test assesses an individual's learning capabilities through descriptive or discursive responses. The study employed an essay-style test to assess factors linked to scientific literacy, critical thinking abilities, and science process skills.

The data collected were analyzed to address research questions, identify issues, and test hypotheses. For this analysis, the study used IBM SPSS Statistics 24 software to facilitate data processing.

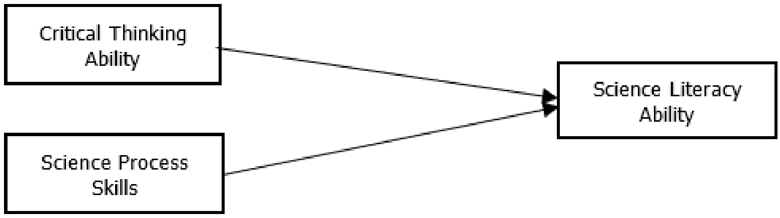

Figure 1. Research Framework

Source: researcher data

H1: Critical Thinking Ability on Students' Science Literacy Ability

H2: Process Skills on Students' Scientific Literacy Ability

3. Result and Discussion

Descriptive Data Analysis

An analysis was conducted for each variable in this study to determine its mean, maximum, minimum, and standard deviation values. Descriptive statistics may be used to portray the data in a clear and straightforward way, allowing us to ascertain the normality of the data distribution.

Table 1. the result of Descriptive Data Analysis

	N	Minimum	Maximum	Mean
Critical Thinking_X1	53	5.00	25.00	18.6792
Process Skills_X2	53	5.00	25.00	15.8491
Y	53	5.00	25.00	17.0755

Source: researcher data

Classic Assumption Test

1. Normality Test

Utilizing the Kolmogorov-Smirnov test was the statistical analysis method. A p-value of less than 0.05 suggests that the distribution of residual data is not normal. A normal distribution is observed in the residual data if the p-value is higher than 0.05.

		Unstandardized Residual
N		53
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	6.53029724
Most Extreme Differences	Absolute	.105
	Positive	.071
	Negative	-.105
Test Statistic		.105
Asymp. Sig. (2-tailed)		.200[c,d]

The Kolmogorov-Smirnov value has a magnitude of 0.105 and a significance of 0.200, according to the test results from Table 2. According to this study's findings, residual data is assumed to have a normal distribution if the significance level of 0.200 is more than 0.05.

2. Multicollinearity Test

The multicollinearity test is conducted to determine whether there is any connection among the independent variables in a regression model [45]. In order for a regression model to be considered valid, it is preferable for the independent variables to be uncorrelated. If a strong correlation exists between the variables, the regression model is not appropriate for accurate analysis. In order to evaluate the existence of multicollinearity, two primary indicators are employed: the Variance Inflation Factor (VIF) and the tolerance value.

a. A threshold of less than 0.10 is commonly employed to detect multicollinearity. The low tolerance number suggests that there is a high degree of predictability in the independent variable based on the other factors, indicating the presence of multicollinearity.

b. The Inflation Factor Variance (VIF) has the following value:

1) If the VIF value is greater than 0.10, it indicates a potential multicollinearity problem. A large variance inflation factor (VIF) indicates a strong correlation between the independent variable and other variables, leading to increased standard errors and unstable model coefficients.

2) When the VIF value is less than 0.10, multicollinearity is not present. In this case, the regression model is considered reliable and the independent variables do not show problematic levels of correlation.

Table 3. Multicollinearity Test Results

Coefficients[a]							
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	2.050	3.896		.526	.601		
Process Skills_X2	.327	.140	.289	2.338	.023	.992	1.008
Critical Thinking_X1	.527	.175	.372	3.010	.004	.992	1.008

The analysis shown in Table 3 reveals that both the tolerance values for Critical Thinking and Process Skills are 0.992. Likewise, the Variance Inflation Factor (VIF) for these variables is 1.008. The results of the multicollinearity test reveal that there is no multicollinearity among the independent variables, since the tolerance values above the threshold of 0.10 and the VIF values are substantially below the cutoff of 10. This lack of multicollinearity is important because it ensures that the predictor variables in the regression model do not excessively correlate with one another, which could otherwise skew the results. Therefore, since each independent variable has a tolerance value more than 0.10 and a VIF value less than 10, the data satisfies the necessary requirements for conducting a reliable regression analysis. This confirmation supports the validity of the regression model, suggesting it can be used effectively for further statistical analysis without concerns about inflated standard errors or unreliable coefficient estimates.

3. Heteroscedasticity Test

A statistical condition known as heteroscedasticity occurs when all of the data in a regression model have unequal variance in the residuals. When residual variance is constant between observations, it is said to be heteroscedastic; when residual variance varies between observations, it is said to be heteroscedastic.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.050	3.896		.526	.601
Process Skills_X2	.327	.140	.289	2.338	.023
Critical Thinking_X1	.527	.175	.372	3.010	.004

According to the above table's heteroscedasticity test findings, every variable's significance is greater than 0.05. Thus, it may be concluded that this regression model does not contain heteroscedasticity.

Multiple Linear Regression Test Results

The Variable Correlation Model of Critical Thinking Ability and Process Skills on Scientific Literacy Ability in Primary School Teacher Education students found the following learning outcomes.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.050	3.896		.526	.601
Process Skills_X2	.327	.140	.289	2.338	.023
Critical Thinking_X1	.527	.175	.372	3.010	.004

a. Dependent Variable: Science Literacy Y

It is clear from the presented regression calculation results that, in the case when the variables of Critical Thinking Ability and Process Skills do not vary, a constant value of 2.050 can be interpreted.

T-test Results (Partial)

To ascertain if an independent variable exerts a statistically significant impact on the dependent variable, employ the t-statistic test. The value obtained from analyzing the Critical Thinking Ability and Process Skills variables is known as the t-count. This t-count value is compared against the t-table to assess its significance with respect to the Scientific Literacy Ability of Primary School Teacher Education students. The significance of this value is interpreted as follows:

a. The null hypothesis (H0) and the alternative hypothesis (H1) are accepted when the tcount value exceeds the t-table value, suggesting a fairly substantial influence of the independent variable on the dependent variable.

b. Both the null hypothesis (H0) and the alternative hypothesis (H1) are rejected when the calculated t-value is less than the critical t-value from the t-table. This indicates that there is no observable impact of the independent variable on the dependent variable.

c. If the p-value is below 0.05, it is considered that the independent variable has a statistically significant influence on the dependent variable.

d. If the p-value exceeds 0.05, it indicates that the independent variable does not have a statistically significant effect on the dependent variable.

Variabel	t	Sig
(Constant)	.526	.601
Process Skills_X2	2.338	.023
Critical Thinking X1	3.010	.004

a. Dependent Variable: Science Literacy _Y

Based on the information in the table above, the following deductions can be made.

a. The t-test for the Critical Thinking variable yielded a t-count value of 3.010 and a t-table value of 2.007 (df = 52) at a significance level of 0.004. The null hypothesis (H0) is rejected in favor of the alternative hypothesis (H1) since the calculated t-value (3.010) exceeds the critical t-value (2.007) and the significance level (0.004) is smaller than the predetermined threshold of 0.05. This indicates that within the group of students who are currently enrolled in the Primary School Teacher Education program, the level of Scientific Literacy Ability is greatly impacted by their Critical Thinking Ability (X1).

b. The t test was conducted on the Process Skills variable, resulting in a tcount value of 2.338. The t table value, with a degree of freedom of 52, was found to be 2.007. The significance threshold used was 0.023. Based on the fact that the t count value exceeds the t table value (2.338 > 2.007) and the significance value is below 0.05 (0.023 < 0.05), we may conclude that hypothesis H2 is accepted. Process Skills, or variable X2, has a major influence on the variable representing Scientific Literacy Ability in students seeking Primary School Teacher Education.

H1 Critical Thinking Skills to Students' Scientific Literacy Abilities

The test results indicate that critical thinking skills significantly affect and enhance students' scientific literacy abilities. The calculated t-value is 3.010, with a significance level of 0.004. These findings align with the research carried out by Septiani et al [46] The study establishes a clear correlation between critical thinking ability and degrees of scientific literacy. Similarly, Sofyan & Amir [47] assert that through influencing a person's attitude, conduct, and character, scientific literacy can enhance a variety of competencies. In research done by Primasari et al [48] it was discovered that pupils' capacities for scientific literacy are impacted by their growing critical thinking abilities. Pupils that are proficient in scientific literacy also have strong critical thinking abilities [49].

Critical thinking skills are fundamental to enhancing students' scientific literacy abilities, enabling them to engage deeply with scientific concepts, methodologies, and real-world applications. These abilities cover a variety of cognitive functions, including as synthesis, analysis, evaluation, and logical reasoning, all of which are critical for comprehending and successfully applying science.

Firstly, analysis is a critical thinking skill that allows students to break down complex information into manageable parts. By analyzing scientific data, students can identify patterns, trends, and relationships, leading to a better understanding of underlying principles. For example, analyzing data from a biodiversity survey can help students recognize the impact of environmental changes on various species.

Evaluation involves assessing the credibility and validity of information, sources, and arguments. This skill is crucial for distinguishing between scientifically sound conclusions and those based on flawed or biased data. When students evaluate the methodology and results of a research study on climate change, they develop the ability to critically assess scientific claims and make informed judgments.

Synthesis, the ability to combine different pieces of information to form a coherent whole, is another key aspect of critical thinking. This skill enables students to integrate knowledge from various scientific disciplines, leading to a more comprehensive understanding of complex issues. For instance, synthesizing information from physics, chemistry, and biology can provide insights into the interconnected nature of ecosystems.

Logical reasoning is essential for constructing and evaluating arguments based on evidence. This skill allows students to develop hypotheses, design experiments, and draw conclusions that are logically sound and scientifically valid. By using logical reasoning to explore the relationship between variables in an experiment, students enhance their ability to think methodically and rigorously.

Critical thinking also encompasses reflecting on one's own thought processes and recognizing personal biases. Metacognition, or thinking about thinking, helps students recognize their cognitive biases and limitations, leading to more objective and accurate scientific inquiry. Encouraging students to reflect on their reasoning during a lab experiment fosters a deeper understanding of scientific practices and principles.

The integration of critical thinking into scientific education fosters dynamic learning and active participation. Students actively engage in their education when they are prompted to question assumptions, engage in discussions about topics, and seek supporting evidence. This active engagement not only enhances their scientific literacy but also prepares them to apply scientific knowledge and critical thinking skills in real-world contexts.

Moreover, critical thinking skills are essential for navigating the vast amount of information available in the digital age. Students equipped with these skills can critically evaluate online sources, identify misinformation, and make informed decisions based on credible scientific evidence. This is especially crucial in an age where information is plentiful but not always trustworthy.

In summary, critical thinking skills are indispensable for developing students' scientific literacy abilities. By fostering analysis, evaluation, synthesis, logical reasoning, and metacognition, educators can equip students with the tools needed to understand, apply, and communicate scientific concepts effectively. These skills not only enhance students' academic performance but also prepare them to become informed, critical thinkers capable of addressing complex scientific and societal challenges.

H2: Science Process Skills to Students' Scientific Literacy Abilities

The tests produced a t-value of 2.338 and a significance value of 0.023. This indicates that Process Skills have a significant influence and can enhance the Scientific Literacy Abilities of students in Primary School Teacher Education. This finding is consistent with the inquiry conducted by Suryanti et al [50]. According to the research, developing process skills can improve students' understanding in scientific education. Process skills are intrinsically linked to scientific literacy due to the fact that scientific literacy encompasses comprehension and application of scientific principles, as well as the critical analysis, assessment, and utilization of scientific knowledge [7]. The scientific process abilities encompass the capacity to observe, collect data, develop hypotheses, plan experiments, evaluate data, and communicate research findings [1], [23].

Science Process Skills (SPS) are essential for improving students' scientific literacy. The abilities of watching, categorizing, measuring, forecasting, and testing are fundamental to scientific inquiry and comprehension.

Firstly, observing is the foundational skill that allows students to gather information about the natural world through their senses. This skill is vital for making accurate descriptions and identifying patterns, which are the basis for further scientific investigation. For instance, when students observe the phases of the moon, they collect data that can lead to broader understanding of celestial movements.

Classifying involves grouping objects or phenomena based on shared characteristics. This skill helps students organize information systematically, making it easier to understand complex concepts. For example, by classifying different types of rocks, students can better comprehend the processes of rock formation and the geological history of Earth.

Measuring is another critical SPS, enabling students to quantify observations. Accurate measurements are essential for making reliable comparisons and testing hypotheses. When students measure the growth of plants under different light conditions, they gain insights into the effects of environmental factors on plant development.

Predicting involves making educated guesses about the outcomes of scientific investigations based on existing knowledge. This skill encourages students to think ahead and consider potential results, fostering a deeper engagement with the scientific method. For instance, the ability to forecast the result of a chemical reaction by considering the characteristics of the substances involved aids students in comprehending the fundamental concepts of chemistry.

The process of hypothesizing, which involves creating testable hypotheses for observations, is a fundamental aspect of scientific research. It fosters students' ability to engage in critical and creative thinking while analyzing the origins of events. By hypothesizing the reasons for a sudden decline in a local frog population, students engage in problem-solving that can lead to actionable conservation efforts.

Experimenting is the hands-on application of scientific methods to test hypotheses. Through experimentation, students learn to control variables, collect data, and draw conclusions based on empirical evidence. Conducting experiments on the effects of different fertilizers on crop yield, for example, provides practical experience in agricultural science.

Finally, interpreting data involves analyzing results and making sense of them. This skill is crucial for drawing valid conclusions and communicating findings effectively. When students interpret data from climate change studies, they contribute to the broader understanding and dissemination of important environmental issues.

By developing SPS, students are better equipped to comprehend scientific concepts, think critically, and solve problems. This not only promotes a more profound comprehension of scientific concepts but also enables students to utilize scientific ideas in practical scenarios, so enhancing their total scientific literacy.

4. Conclusion

The findings of this research support the research hypotheses: 1) Critical Thinking Skills have a significant positive relationship and influence on students' scientific literacy abilities; 2) There exists a substantial and favorable correlation between the proficiency in conducting scientific procedures and the level of scientific literacy among students. The study's findings indicate that science training in higher education should give priority to teaching students the skill of critical thinking by showcasing their competence in scientific methodologies. Additionally, in science education at the higher education level, especially in the Primary School Teacher Education program, teaching models and approaches should be utilized to enhance students' process skills and critical thinking skills.

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