

Examining the Relationship Between Science Literacy, Science Process Skills, and Higher-Order Thinking Skills in Elementary Teacher Education Students

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ABSTRACT

Science literacy is crucial for prospective elementary school teachers to enhance their higher-order thinking skills. Science education that emphasizes the development of higher-order thinking skills is based on science process skills. This research aims to determine the relationship between science literacy and science process skills on HOTS (Higher Order Thinking Skills) cognitive learning outcomes. The study employs a quantitative approach with a correlational method. Data collection for the variables of science literacy and HOTS cognitive learning outcomes was conducted through written tests, while data collection for the science process skills variable was carried out through performance tests developed by the researcher. The population consists of all 2022 Elementary School Teacher Education Study Program or PGSD students in Sebelas Maret University, with random cluster sampling. Data analysis employs multiple correlation analysis. The results indicate a positive and significant relationship between science literacy and science process skills on HOTS cognitive learning outcomes, with a significance value of $0.000 < 0.05$ and a Pearson correlation value of 0.495. There is a positive and significant combined relationship between science literacy and science process skills on HOTS (Higher Order Thinking Skills) cognitive learning outcomes, with a moderate level of correlation. The findings of this study have important implications for students' enhancement of their science process skills, science literacy, and HOTS cognitive learning outcomes. This research positively impacts academic programs by encouraging students and implementing relevant teaching strategies and methods, thereby improving science literacy, science process skills, and HOTS cognitive learning outcomes.

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1. INTRODUCTION

Natural Science (IPA) plays a pivotal role in human life, preparing students with essential skills to navigate the challenges of the 21st century, which demands technological proficiency, critical thinking, creativity, and effective problem-solving. Science encompasses processes, products, and attitudes, making its study inseparable from the skills of scientific inquiry, mastery of scientific knowledge, and the cultivation of scientific attitudes (Aisah, 2020). Science education aims to enable students to understand themselves and their surroundings and to apply this understanding in adapting to changes in their daily lives (Hardiansyah & Wahdian, 2023). For this to be effective, both teachers and pre-service elementary school teachers must possess a thorough understanding of the various components of the learning process, particularly a deep comprehension of science concepts (Surya, Tajqiyah, Refiarni et al., 2023). Research by Resbiantoro & Nugraha (2017) underscores the importance of pre-service elementary school teachers having an accurate and solid grasp of scientific concepts. As noted by Sudijono (2017), true understanding in learning is demonstrated by the ability to describe or explain concepts clearly in one's own words, reflecting the learner's capacity to reconstruct and effectively communicate acquired knowledge. Effective learning is ultimately measured by students achieving their learning rights and demonstrating mastery of competencies, as evidenced by their learning outcomes (Handayani, 2023).

Learning outcomes serve as indicators of an individual's grasp of the material presented, offering valuable insights into their learning journey and developmental progress (Rahim et al., 2023). Benjamin S. Bloom conceptualized learning outcomes as comprising three domains: cognitive, affective, and psychomotor (Putra, Yaqin, & Saputra, 2024). The cognitive domain, specifically associated with intellectual development, encompasses cognitive learning outcomes (Nurlindayani, Setiono, & Suhendar, 2021). These outcomes represent students' intellectual capacities, thus necessitating that the learning process, practice, and evaluation methods consistently integrate cognitive components (Fenanlampir, 2021). Cognitive learning outcomes ultimately reflect students' achievements in the cognitive domain, encompassing the reception of external stimuli, information retention, and processing, all of which are quantified through test scores.

Students' cognitive knowledge reflects their mastery of the cognitive domain. The cognitive domain includes behaviors focusing on intellectual aspects such as knowledge, as well as thinking skills involving both lower-order thinking skills (LOTS) and higher-order thinking skills (HOTS) (Nabilah, Sitompul, & Hamdani, 2020). This study focuses on HOTS cognitive learning outcomes because it is understood that HOTS students tend to achieve better learning outcomes, develop performance more optimally, and reduce potential weaknesses during the learning process (Ujang Suparman, 2021). HOTS are crucial for developing thinking skills as they involve information gathering, problem-solving innovation, and decision-making, fundamentally influenced by cognitive abilities such as critical thinking and problem-solving across various disciplines (Munar, Winarti, Nai'mah, et al., 2022).

Higher-order thinking skills (HOTS) refer to the abilities required for critical and creative problem-solving. These advanced skills involve analyzing, evaluating, deconstructing, and addressing complex issues (Saraswati & Agustika, 2020, p. 260). As outlined by the Ministry of Education and Culture, HOTS, when applied to questioning techniques, correspond to Cognitive Level 4 (analyzing), Cognitive Level 5 (evaluating), and Cognitive Level 6 (creating) (Sumaryanta, 2018, p. 504).

High-level thinking skills need to be cultivated from elementary school so that students become accustomed to advanced thinking, which serves as a foundation for further education. Additionally, high-level thinking enables students to express ideas or responses logically. This aligns with the view of Hendriawan and Usmaedi (2019, p. 77), who assert that high-level thinking skills also enable students to present ideas in an argumentative, logical, and confident manner, whether in written, oral, or action forms. Possessing Higher Order Thinking Skills (HOTS) allows students to distinguish between detailed and brief responses, and to solve problems both in academic contexts and in everyday life.

The essence of meaningful science concepts lies in the integration of theoretical reasoning and actual scientific events (Nugraha, 2022). Danianty & Sari (2022) State that to achieve meaningful learning objectives in science, students need strong literacy and science process skills, enabling them to practice and develop scientific concepts in daily life. Students can achieve a meaningful level of science learning if they have good science literacy skills (Rakhmawan, Setiabudi, & Mudzakir, 2015). According to PISA (Programme for International Student Assessment) data, Indonesian students' science literacy skills are lower compared to the international average, although Indonesia's ranking in science literacy has improved by 5-6 positions since 2018 (OECD, 2023). A scientifically literate person can accurately apply scientific concepts, principles, laws, and theories to interact with their environment and use scientific processes to solve problems, make decisions, and understand current natural conditions (Listiani, Susilo, & Sueb, 2022).

Science process skills in science learning are crucial because they enable the achievement of science learning goals through inquiry-based activities (Angelia, Supeno, & Suparti, 2022). These skills are one of the most frequently used cognitive abilities and an important goal in science teaching (Kurniawan & Fadli, 2016). Scientists use science process skills in scientific research, which is essential in science learning because it bridges learning objectives by providing direct experiences (Walil, Suryawati, & Akmal, 2021). The development of science process skills is critical as it promotes HOTS necessary for everyday life. Science process skills help students solve problems they face in daily life, both directly and indirectly (Saputra, Widiyanto Atmojo, & Saputri, 2023). Science literacy is key for students to enhance HOTS (Maya Probosari, Sajidan, Suranto, et al., 2016). Meanwhile, science learning focused on developing HOTS is based on science process skills (Setyawarno & Kurniawati, 2022).

Science education involves not only the understanding of content but also mastery of process skills and scientific attitudes (Nuryah, Nuha, & Wahyuni, 2022). Angelia, Supeno, & Suparti (2022) explain that in science education, science process skills are crucial as they facilitate the achievement of science learning goals through inquiry-based activities. These process skills are among the most frequently used cognitive abilities and are significant objectives in science teaching (Kurniawan & Fadli, 2016). Science process skills are integral to scientific procedures in science education (Geovana, Akbar, & Supardi, 2023). They are fundamental components for developing concepts and play a vital role in the science learning process (Wijaya, Rohman, & Utari, 2018). Wijayanti (2023) notes that science process skills may decline due to insufficient attention to HOTS-based process skills, leading to issues in the process and final outcomes of learning. Based on this perspective, it can be concluded that science process skills are essential for enhancing students' abilities, particularly in science education. The development of science process skills is critical as it fosters higher-order thinking skills necessary for everyday life.

Previous research on similar topics includes Nugraha (2022), which showed a significant relationship between science literacy and science learning outcomes. Additionally, Agustina, Saputra, & Clara (2018) found a strong correlation between science process skills (SPS) and student learning outcomes in animal anatomy practical courses. These studies demonstrated correlations between science literacy and learning outcomes, as well as between science process skills and learning outcomes. However, there is a limited amount of research specifically investigating the relationship between science literacy, science process skills, and HOTS cognitive learning outcomes. This study differs from previous research by focusing on exploring the relationship between science literacy and science process skills in relation to HOTS cognitive learning outcomes among Elementary School Teacher Education (PGSD) students. This research is significant as it aims to explore the connections between science literacy, science process skills, and cognitive learning outcomes in HOTS. The topic is relevant in the current context, reflecting students' ability to apply knowledge and skills critically, analytically, and creatively to solve complex problems and make high-level decisions, which is essential for success in education and professional life. Science process skills are crucial for students to face increasingly difficult future challenges (Hadiya, 2018). It is important for prospective teachers to master Science Process Skills (SPS) so that, as future educators, they have a solid understanding of SPS and can

effectively implement them in classroom instruction (Mahmudah, Maulidah, & Sulistyarningsih, 2022). In process-oriented learning, students will better understand the meaning of learning through engagement in process activities, rather than merely receiving theories, principles, or concepts, and will also apply them in real life. Alongside the importance of science process skills, good literacy is expected to enhance understanding of science concepts. This is because science literacy enables individuals to understand and utilize scientific knowledge to recognize, collect, and interpret scientific phenomena, make judgments based on facts, and understand the nature of science (Irsan, 2020).

Science literacy is key for students to enhance higher-order thinking skills (Maya Probosari, Sajidan, Suranto, et al., 2016). This is supported by Setyawarno & Kurniawati (2022), who state that "science learning focused on developing higher-order thinking skills involves a scientific approach that includes observing, questioning, experimenting, connecting, and communicating, with these elements being both fundamental and integrated into science process skills," indicating that science education prioritizing the development of higher-order thinking skills is based on science process skills.

Optimal learning outcomes in the teaching process are desired by all stakeholders. Therefore, it is assumed that students with superior science literacy and science process skills can engage deeply in learning and apply it in practice. Good understanding and implementation by PGSD students are considered to positively impact their cognitive learning outcomes. This is why this study aims to investigate the relationships between science literacy, science process skills, and HOTS cognitive learning outcomes. This research is expected to clarify the relationship between science literacy, science process skills, and cognitive learning outcomes in the context of science education. If evidence of such relationships is found, the findings could provide a basis for reorienting science education. Thus, based on the background outlined above, the author is interested in exploring HOTS cognitive learning outcomes among PGSD students and the relationships between science literacy and science process skills.

Based on the problem formulation above, the objectives of this research are: (1) To determine the positive and significant relationship between science literacy and HOTS cognitive learning outcomes among PGSD students; (2) To determine the positive and significant relationship between science process skills and HOTS cognitive learning outcomes among PGSD students; (3) To determine the positive and significant combined relationship between science literacy and science process skills with HOTS cognitive learning outcomes among PGSD students.

2. METHODS

This study employs a quantitative approach with a correlational method, which aligns with the research objectives to identify the relationships between science literacy (X1) and science process skills (X2) with HOTS (Higher Order Thinking Skills) and cognitive learning outcomes (Y). This research aims to determine the relationship between science literacy (X1) and science process skills (X2) on HOTS cognitive learning outcomes (Y). The objectives of this research are reinforced by the perspective of Ibrahim et al. (2018), who state that the aim of correlational research is to identify, using correlation coefficients, how variation in one variable is related to variation in one or more other variables. Correlated variables are intended to identify the relationships between variables or to use these relationships for prediction purposes (Emzir, 2010). The research is based on measuring quantities and applied to quantitative phenomena, thus the authors statistically analyze the collected data to obtain findings. Correlation refers to the relationship between two or more paired variables or two or more data sets (Etfita, 2019). This research was conducted on Elementary School Teacher Education Study Program (PGSD) students at UNS in 2022. The study population consisted of 212 students, with 69 students selected as the research sample based on cluster random sampling technique. The sampling technique applied in this study is cluster random sampling using the One-Stage Cluster Sampling method, which involves dividing the population into groups or clusters. Several clusters are then randomly selected to represent the population, and all elements within the selected clusters are used as the research sample (Fauzy, 2019). Using the one-stage cluster sampling method, clusters (classes)

were randomly chosen from the total number of clusters, specifically 2 clusters from a total of 6 clusters. By randomly selecting 2 clusters out of the 6 available and using the average cluster size, approximately 69 students will be obtained as the sample if all students in the selected clusters are included.

Data collection techniques include written tests for variables X1 and Y, and performance tests for variable X2. Instrument validity was conducted using Aiken's content validity. The research consists of two steps of data analysis techniques: research prerequisite tests and hypothesis testing. The prerequisite analysis conducted in this investigation includes tests for normality and linearity. Normality testing of the three variables is performed using the Kolmogorov-Smirnov test and SPSS 20. Data are considered normally distributed if the significance value or Asymp. Sig (2-tailed) is greater than 0.05. Linearity testing is conducted to identify the linearity of the data and to determine whether the relationship between the independent and dependent variables is linear. This analysis is performed using SPSS 20 software, utilizing the Test for Linearity at a significance level of 0.05.

A simple correlation hypothesis test will be conducted to examine whether there is a relationship between X1 and Y and between X2 and Y. The formula used in this hypothesis test is Pearson Product Moment correlation, which aims to test whether there is a relationship between an independent variable and a dependent variable (Sugiyono, 2022). Subsequently, the researcher will use Multiple Correlation Testing to evaluate the hypothesis regarding the relationship between the independent variables X1 and X2 and the dependent variable Y. After obtaining the correlation values of variables X1 and X2 with Y, the interpretation process will be carried out to assess the strength of the relationships between the variables. The hypothesis conclusion can then be drawn from the calculations: if the Sig. F Change value is greater than 0.05, the null hypothesis (H_0) is rejected; if the Sig. F Change value is less than 0.05, the null hypothesis (H_0) is accepted.

3. FINDINGS AND DISCUSSION

The statistics applied in this study involve describing the data for the variables of science literacy, science process skills, and HOTS cognitive learning outcomes. The aim is to map and categorize the scores for each variable. The data description in this study includes mean, median, mode, maximum value, minimum value, standard deviation, and variance.

3.1. Data Description

Descriptive statistics in this study play a crucial role in providing a fundamental understanding of the distribution and characteristics of the variables under investigation. By detailing the mean, median, mode, maximum value, minimum value, standard deviation, and variance, the researcher can gain deep insights into the distribution patterns and the extent to which data varies around the central distribution for the variables of science literacy, science process skills, and HOTS cognitive learning outcomes. This information not only aids in identifying general trends and variations within the sample but also in determining how the data is distributed and whether there are significant patterns or anomalies. Understanding these aspects is essential before proceeding to hypothesis testing, as it provides a solid foundation for more complex analysis and more accurate conclusions regarding the relationships between the studied variables.

3.1.1 Science Literacy

Science literacy refers to an individual's ability to understand, explain, and apply concepts, processes, and phenomena scientifically within the field of science, and to utilize this knowledge to address everyday problems (Nurpratiwi et al., 2023; OECD, 2023; Sutrisna, 2021). Science literacy is measured by the score obtained by students after completing objective tests related to aspects of scientific competency that can be assessed, such as explaining phenomena scientifically, using scientific evidence, and identifying scientific questions. Data analysis for science literacy shows an average test score of 72.72; median of 76; mode of 76; maximum value of 94; minimum value of 47; standard

deviation of 10.669; and variance of 113.82. The histogram showing the frequency distribution of variable X1 is presented below.

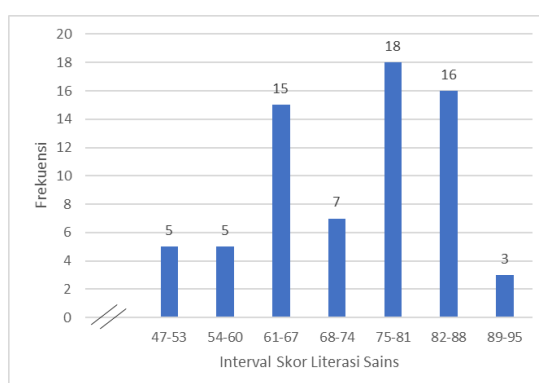


Figure 1. Histogram of science literacy frequency distribution

Based on the histogram of science literacy frequency data, it is evident that the science literacy test has an interval length of 7 and consists of 7 classes. The highest frequency of science literacy scores is observed in the interval 75-81, with a total of 18 students. The second highest frequency is in the interval 82-88, with 16 students. The third highest frequency is in the interval 61-67, with 15 students. Conversely, the lowest frequency is found in the interval 89-95, with 3 students. The second lowest frequencies are in the intervals 47-53 and 54-60, each with 5 students. The third lowest frequency is in the interval 68-74, with 7 students. All collected data align with the total of 69 students, representing 100% of the sample.

3.1.2 Science Process Skills

Scientific process skills are divided into two categories: basic skills and integrated skills. Basic skills include observation, classification, prediction, measurement, and communication, while integrated skills encompass detailing and formulating variables, explaining data, conducting experiments, and drawing conclusions (Fadilla, Ramalis, & Samsudin, 2023; S. A. Ismail, 2023; Riskawati, Saad, & A, 2022). Scientific process skills are assessed based on the scores obtained by students after performing observational tasks, which measure their ability to apply the scientific method systematically and meticulously. This includes focusing on observing, formulating hypotheses, conducting measurements, performing experiments, interpreting results, and communicating findings.

Data analysis for science process skills results in an average score of 72.94; median of 73; mode of 73; maximum value of 86; minimum value of 61; standard deviation of 6.245; and variance of 38.997. The histogram illustrating the frequency distribution of variable X2 is shown below.

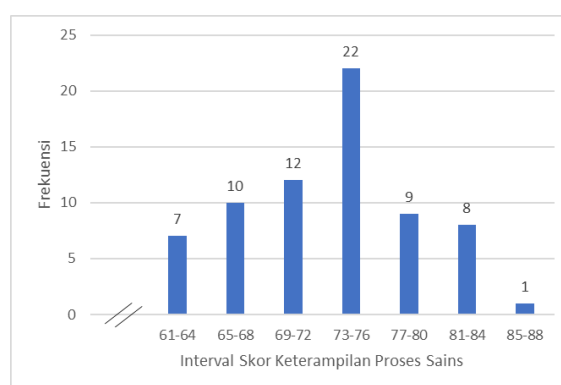


Figure 2. Histogram of science process skills frequency distribution

Based on the histogram of scientific process skills data, the interval length is 4 and there are 7 classes. The highest frequency of scientific process skills scores is observed in the interval 73-76, with a total of 22 students. The second highest frequency is found in the interval 69-72, with 12 students. The third highest frequency is in the interval 65-68, with 10 students. The fourth highest frequency is in the interval 77-80, with 9 students. Conversely, the lowest frequency is observed in the interval 85-88, with only 1 student. The second lowest frequency is in the interval 81-84, with 8 students. The third lowest frequency is in the interval 61-64, with 7 students. All collected data align with the total of 69 students, representing 100% of the sample.

3.1.3 HOTS Cognitive Learning Outcomes

Cognitive Learning Outcomes in HOTS (Higher-Order Thinking Skills) refer to the educational results that encompass the highest cognitive levels and are assessed using questions that emphasize higher-order thinking abilities (Herman et al., 2022; Nurlindayani, Setiono, & Suhendar, 2021). Cognitive Learning Outcomes in HOTS represent the scores obtained by students after completing HOTS cognitive learning tests, which are in the form of essay questions related to the HOTS cognitive levels (C4, C5, and C6) achieved following the instruction.

Data analysis for HOTS cognitive learning outcomes yields an average score of 63.20; median of 63; mode of 63; maximum value of 81; minimum value of 38; standard deviation of 10.549; and variance of 111.282. The histogram displaying the frequency distribution of variable Y is presented below.

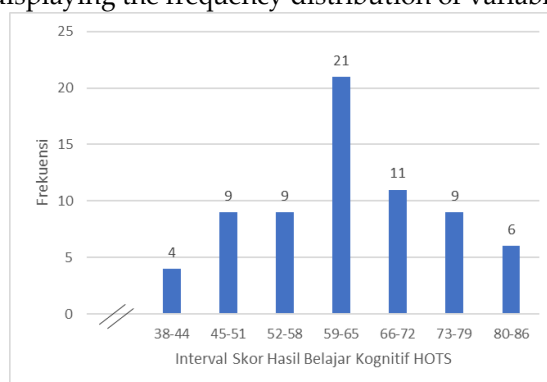


Figure 3. Histogram of HOTS cognitive learning outcomes frequency distribution

Based on the histogram of scientific process skills data, the interval length is 7 and there are 7 classes. The highest frequency of HOTS (Higher-Order Thinking Skills) cognitive learning outcomes is observed in the interval 59-65, with a total of 22 students. The second highest frequency is found in the interval 66-72, with 11 students. The third highest frequencies are in the intervals 45-51, 52-58, and 73-79, each with 9 students. Conversely, the lowest frequency is observed in the interval 38-44, with 4 students. The second lowest frequency is in the interval 80-86, with 6 students. All collected data align with the total of 69 students, representing 100% of the sample.

3.2 Prerequisite Tests

The normality of the data was tested using the Kolmogorov-Smirnov test with the help of SPSS 20.

Table 1. Data Normality Test

Asymp. Sig. (2-tailed)	Criteria	Conclusion
0.969	Asymp. Sig (2-tailed) > 0,05	Normally distributed

Table 1 shows that the Asymp. Sig (2-tailed) value is 0.969, which is higher than the α level of 0.05. This indicates that the residual data distribution is normal.

The linearity of the data was tested using SPSS 20, with the Test for Linearity at a significance level of 0.05.

Table 2. Linearity Test of Science Literacy with HOTS Cognitive Learning Outcomes

Deviation from linearity	Criteria	Conclusion
0.141	Deviation from linearity > 0.05	Linear

From Table 2, the significance value of deviation from linearity is 0.141, exceeding the alpha (α) value of 0.05, indicating that the relationship between science literacy and HOTS cognitive learning outcomes is linear.

Table 3. Linearity Test of Science Process Skills with HOTS Cognitive Learning Outcomes

Deviation from linearity	Criteria	Conclusion
0.051	Deviation from linearity > 0.05	Linear

Table 3 shows a significance value of deviation from linearity of 0.051, which exceeds the alpha (α) value of 0.05, indicating that the relationship between science process skills and HOTS cognitive learning outcomes is linear.

Based on the results of the prerequisite tests, which show that the data distribution is normal and linear, hypothesis tests 1 and 2 can be continued with Pearson Product Moment correlation tests to determine if there is a relationship between the independent and dependent variables [21], using SPSS 20 at a significance level of 0.05.

3.3 Hypothesis Testing

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,495^a	,245	,222	9,302	,245	10,728	2	66	,000

a. Predictors: (Constant), Keterampilan Proses Sains, Literasi Sains

b. Dependent Variable: Hasil Belajar Kognitif HOTS

Figure 4. Hypothesis Test of Science Literacy and Science Process Skills on HOTS Cognitive Learning Outcomes

The results of the hypothesis test indicate that the significance value of the multiple correlation coefficient between science literacy and science process skills (X1 and X2) with HOTS cognitive learning outcomes (Y) is $0.000 < 0.05$, with a Pearson correlation value of 0.495. Based on these findings, it can be concluded that the null hypothesis is accepted with a moderate level of association. Thus, there is a positive and significant joint relationship between science literacy and scientific process skills with HOTS (Higher-Order Thinking Skills) cognitive learning outcomes. The null hypothesis, which posits a positive and significant joint relationship between science literacy and scientific process skills with HOTS cognitive learning outcomes, is accepted with a moderate level of correlation. This indicates a

positive and significant joint relationship between science literacy and science process skills with HOTS cognitive learning outcomes. A simultaneous increase in science literacy and science process skills is associated with an improvement in HOTS cognitive learning outcomes.

Discussion

In this section, we delve into an in-depth analysis of the research findings, interpreting how the data aligns with each hypothesis. By examining the results in the context of existing literature and theoretical frameworks, we aim to provide a comprehensive understanding of the implications and nuances of each hypothesis. This discussion will highlight both expected outcomes and any deviations from anticipated results, thereby offering insights into potential factors that may have influenced the findings. Through this analysis, we seek to clarify how the data supports or refutes each hypothesis and to explore broader implications for future research and practice.

Relationship Between Science Literacy and HOTS Cognitive Learning Outcomes

The first hypothesis test indicates that the significance value of the simple correlation coefficient (Sig. (2-tailed)) between science literacy (X1) and HOTS cognitive learning outcomes (Y) is $0.000 < 0.05$. This suggests that there is a positive and significant relationship between science literacy and HOTS cognitive learning outcomes.

The positive and significant relationship between science literacy and HOTS cognitive learning outcomes implies that as science literacy improves, HOTS cognitive learning outcomes also increase. This is consistent with constructivist learning theory, which posits that individuals construct knowledge and understanding based on their experiences (Nurfatimah, 2019). Science literate individuals do not merely receive information but interpret it based on their existing knowledge and experiences. Jean Piaget's constructivist theory assumes that children use concepts to build their understanding of the world through active interaction with their environment (Suryana, Aprina, & Harto, 2022). Anderson et al. (2001) further argue that success in science learning reflects proficiency in understanding and mastering scientific content and concepts (Nugraha, 2022). Science literacy involves the ability to understand, explain, and apply scientific concepts, processes, and phenomena, and to use this knowledge to solve everyday problems (Astuti, 2018; Nurpratiwi, Hamdu, & Sianturi, 2023; OECD, 2023a; Sutrisna, 2021). Science literacy is crucial for students to develop higher-order thinking skills (Maya Probosari, Sajidan, Suranto, & Prayitno, 2016). In this study, a stronger grasp of scientific concepts correlates with better HOTS learning outcomes, as science literacy encourages students to engage more effectively in HOTS cognitive efforts.

Students with strong science literacy are better equipped to make decisions and face challenges in their lives (Ristina, Linuwih, & Nuswowati, 2019). Effective science literacy requires scientific thinking skills, including comprehension, application, recall, analysis, and evaluation of scientific phenomena to address problems and enhance cognitive abilities (Yusuf, Hidayatullah, & Tauhidah, 2022). Rini, Dwi Hartantri, & Amaliyah (2021) emphasize that literacy competencies focus on how individuals approach answering questions and solving scientific challenges, necessitating logic, reasoning, critical, and creative analysis. Therefore, it is important to examine the characteristics of science literacy competencies among students.

These findings are consistent with Nugraha's (2022) research, which states that students' science learning outcomes are positively correlated with their science literacy levels, demonstrating an empirical connection between the two. Similarly, Armas, Ramlawati, & Syahrir (2019) found a significant relationship between science literacy and academic performance, indicating that students' learning achievements are influenced by their science literacy.

In conclusion, there is a positive and significant relationship between science literacy and HOTS cognitive learning outcomes. This research underscores the importance of enhancing science literacy to improve HOTS cognitive learning outcomes.

Relationship Between Scientific Process Skills and HOTS Cognitive Learning Outcomes

The second hypothesis test shows that the significance value of the simple correlation coefficient between scientific process skills (X2) and HOTS cognitive learning outcomes (Y) is $0.009 < 0.05$, indicating a positive and significant relationship.

The positive and significant relationship between scientific process skills and HOTS cognitive learning outcomes means that an increase in scientific process skills is accompanied by an increase in HOTS cognitive learning outcomes. This aligns with Gagne's learning theory, which emphasizes the importance of scientific process skills in science education, including knowledge of scientific concepts and principles that can be acquired when students have the foundational skills needed for effective science application (Santi, Kresnadi, & Rosnita, 2018). Setyawarno & Kurniawati (2022) also indicate that science education focused on developing higher-order thinking skills is based on scientific process skills. Science-literate students can apply scientific concepts, process skills, scientific attitudes, and values in their interactions and decision-making, particularly in daily life (Dwiyanti & Rahayuni, 2019). This research supports the theory by helping students apply scientific knowledge practically and solve complex problems, which are components of HOTS. Thus, improving scientific process skills directly relates to enhanced HOTS cognitive learning outcomes, consistent with Gagne's emphasis on foundational skills necessary for effective science application. Through their process skills, students can refine their thinking and support their learning outcomes, particularly in enhancing higher-order thinking abilities.

These findings are in line with previous research on the relationship between scientific process skills and learning outcomes (Agustina, Saputra, & Clara, 2018). The study revealed a strong relationship between scientific process skills (KPS) and students' learning outcomes in anatomy practical courses. The study also highlighted that practical work is a valuable means of developing scientific process skills. Mandasari, Iwan, & Damopolii (2021) assert that scientific process skills positively impact learning outcomes, especially in biology education, significantly improving learning outcomes. Thus, higher scientific process skills lead to better learning achievements.

In summary, there is a positive and significant relationship between scientific process skills and HOTS cognitive learning outcomes. The research highlights the benefits of improving scientific process skills to enhance HOTS cognitive learning outcomes.

Relationship Between Science Literacy and Scientific Process Skills with HOTS Cognitive Learning Outcomes

The third hypothesis test reveals that the significance value of the simple correlation coefficient between science literacy and scientific process skills (X1 and X2) and HOTS cognitive learning outcomes (Y) is $0.000 < 0.05$, indicating a positive and significant joint relationship.

The simultaneous positive and significant relationship between science literacy and scientific process skills with HOTS cognitive learning outcomes suggests that increases in both science literacy and scientific process skills are associated with higher HOTS cognitive learning outcomes.

This relationship is consistent with constructivist theory, which emphasizes that knowledge is constructed through cognitive processes where individuals actively create meaning from their experiences and interactions with their environment (Abdiyah & Subiyantoro, 2021). Jean Piaget explained that knowledge is built through assimilation and accommodation, highlighting the importance of active knowledge development, similar to the focus on science learning processes (Windarta, 2020). In 21st-century science education, constructivism involves students' ability to understand, analyze, and apply concepts through experimental groups and relevant teaching materials to enhance learning outcomes (Riyanti, Cahyono, Haryani, et al., 2021).

Constructivism epistemologically emphasizes that students develop their knowledge through interactions with their environment (Nurfatimah, 2019). This theory is highly relevant to scientific process skills, which involve active experimentation and investigation. Astalini et al. (2023) support this by noting that scientific process skills involve experimental activities using inquiry-based methods

and are generally conducted through practical work. Constructivism also stresses the importance of prior experiences and context in learning (Suryana, Aprina, & Harto, 2022), which relates to science literacy, often relying on linking new concepts with existing knowledge. Ismawati, Leksono, & Harwanto (2023) find that individuals with strong literacy can use their knowledge to identify problems, learn new things, explain concepts, and analyze data related to their field of study. In this study, students are expected to actively engage in learning to construct understanding of scientific concepts through direct experience and interaction with their environment, which strengthens their learning outcomes.

The relationship between science literacy and scientific process skills with HOTS cognitive learning outcomes also pertains to information processing theory. According to Byrnes, information processing theory involves environmental aspects crucial for learning, defined as the effort to acquire and store information in short-term and long-term memory, with learning processes occurring internally (Suryana, Lestari, & Harto, 2022). Individuals select and attend to aspects of their environment, transform and rehearse information, relate new information to existing knowledge, and organize knowledge to make it more meaningful and comprehensible (Mayer, 1996). Researchers assume that all cognitive processes, including seeing, experiencing, rehearsing, thinking, problem-solving, remembering, forgetting, and imagining, involve information processing (Rafiq, 2015). Thus, this theory provides a useful framework for understanding how students process and store information received during science learning. Science literacy and scientific process skills support a deeper understanding of scientific concepts and their interrelationships.

Cognitive learning outcomes reflect students' conceptual understanding (Ilma, Al-Muhdhar, Rohman, & Saptasari, 2020). Students' science literacy enhances their understanding of concepts within science subjects (Suwito, Asdar, & Safira, 2022). A strong understanding of scientific concepts positively contributes to improved cognitive learning outcomes. Danianty & Sari (2022) explain that to meet science learning objectives, students need robust literacy and process skills, enabling them to apply, practice, and develop scientific concepts in everyday life. Meaningful science concepts lie in the integration of theoretical reasoning and actual scientific events (Nugraha, 2022). Students achieve meaningful science learning when they possess good science literacy (Rakhmawan, Setiabudi, & Mudzakir, 2015). Science learning involves not only understanding products but also mastering process skills and scientific attitudes (Nuryah, Nuha, & Wahyuni, 2022).

Scientific process skills are fundamental components of scientific procedures within science education (Geovana, Akbar, & Supardi, 2023). These skills are essential for developing a robust understanding of scientific concepts, making them critical for effective science learning (Wijaya, Rohman, & Utari, 2018). By fostering these skills, educators enable students to engage actively with scientific concepts, promoting deeper comprehension and application. Consequently, the cultivation of scientific process skills is indispensable for building a strong scientific foundation, empowering students to excel in both academic and practical scientific endeavors.

In conclusion, the findings of this research underscore the significant relationships among science literacy, scientific process skills, and higher-order thinking skills (HOTS) cognitive learning outcomes. The data affirm that students with strong science literacy and well-developed scientific process skills exhibit higher HOTS cognitive outcomes, reinforcing the idea that these foundational skills are essential for critical thinking and problem-solving. The integration of science literacy and process skills not only enhances students' understanding of scientific concepts but also prepares them to apply this knowledge in real-world contexts. These results align with constructivist and information processing theories, emphasizing that learning is an active, experiential process in which students construct understanding through meaningful interaction with their environment. Overall, this research contributes to a broader understanding of the factors that foster higher-order cognitive abilities, providing valuable insights for educators aiming to design curricula that enhance both scientific literacy and cognitive learning outcomes. Future research may build on these insights to further explore pedagogical strategies that

effectively develop these critical skills, thereby enhancing students' overall academic and practical capabilities in science.

4. CONCLUSION

This study concludes that there is a positive and significant relationship between science literacy and higher-order thinking skills (HOTS) cognitive learning outcomes among PGSD students, with a moderate correlation ($R = 0.476$) and a significance of 0.000. Similarly, scientific process skills also show a positive, though weaker, correlation with HOTS outcomes ($R = 0.311$, significance of 0.009). When combined, science literacy and scientific process skills together demonstrate a moderate positive relationship with HOTS outcomes ($R = 0.495$, significance of 0.000). These findings highlight that improving students' science literacy and scientific process skills can enhance their cognitive learning outcomes in HOTS. The study underscores the value of developing these skills through experiential learning, where students engage directly with scientific concepts in meaningful ways. For educators, this research emphasizes the importance of implementing teaching strategies that cultivate science literacy and process skills, thus fostering students' critical thinking and problem-solving abilities in science.

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