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Exploring the Relationship between Logical Reasoning Skills, Scientific Literacy, and Academic Achievement in Science Courses Among Secondary Students: A Mixed Method Study

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Abstract: This study explores the correlation between Scientific Literacy (SL) results from PISA 2015 released items, the Test of Logical Thinking (TOLT), and Science Score Achievement (SSA). The method of this study used an explanatory sequential research design with cross-sectional and convenience sampling. Ninety-two 15-year-old students and science teachers participated. The correlation between SL, TOLT, and SSA was positive but moderately weak. The average SL score was low at 33.04%. TOLT results showed that 64.13% of students demonstrated concrete reasoning, 32.61% proportional reasoning, and 3.26% formal reasoning. SSA scores averaged 81.90, with 53 students scoring above average. Interviews with teachers suggested low SL and LT scores resulted from a lack of hands-on activities, as teachers relied heavily on lectures. Science textbooks also lacked inquiry-based learning tasks. The limitations of this research are that it does not cover gender comparison, school curriculums, or school locations, whether urban or suburban. The psychological aspects regarding the students' interest or efficacy are not included in the discussion or provided. Also, students with positive learning experiences in science have good results in SL, and TOLT has not been proven empirically.

Keywords: Assessment; Logical thinking; Science education; Scientific literacy; Students science achievement

Introduction

Scientific literacy is a goal in science education, but many countries still lack convergence about scientific literacy in definitions, strategy, and application (Vieira et al., 2017). Most of across countries assess students' scientific literacy by Programme for International Student Assessment (PISA) According to Bybee et al. (2011), the PISA assessment is different from other assessments. Most assessments reflect on what students have learned and review the knowledge and skills that are determined by the science curriculum. While PISA assesses students in present knowledge, attitudes, and skills for the future. Therefore, the PISA assessment expects students to have the ability to apply knowledge and skills. Also, PISA results regarding scientific literacy determine the quality of education. PISA suggests that policymakers and practitioners improve education in quality, equity, and efficiency because PISA states the students' competence in ability of knowledge and skills, motivation, attitudes, emotions, and other social and behavioral components (Schleicher, 2007). Other causes include PISA, which assessed 15-year-old students across the countries regarding their performance in scientific literacy, mathematical literacy, and reading literacy. It is strengthen by the finding shows that some countries have good results consistently with the strong education system and excellent learning outcome in

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developed countries (Schleicher, 2009). The result of PISA scores is taken serious by several countries which they revise the educational system without considering the differences between the background of the nation (Özer, 2020).

The implications of PISA scores also affect the curriculum policy in Indonesia. Indonesia implemented a new curriculum, which improves student-centered learning and address the disparities of socio-economic and uses technology effectively (Bilad et al., 2024). It shows that Indonesia's PISA result is still in low rank, but in 2022, it showed better results than in 2018, improving 5-6 rank (Siaran Pers, Kementerian). In scientific literacy, Indonesian students have improved by six positions from 2018. Even though Indonesia's PISA result is still in the lower position. There was a strong correlation between Indonesian students' poor comprehension and their poor scientific literacy (Dewi et al., 2019). Up until 2013, there was almost little interest in scientific literacy among Indonesian scholars. Indonesian research indicates a rising trend starting in 2014, with the percentage of the research is 19.57% and 2017 is 33.33% (Ni'mah, 2019).

Scientific literacy has various domains, Indonesian students' results in the domain of explaining the phenomenon scientifically showed 34%, while the interpretation data and scientific evidence skills of the students showed 13% (Indana et al., 2018). At the high school level, the profile of the scientific literacy domain is low. The context dimension domain at two high school shows 38% and 40%, and the competency dimension shows 39% and 39%. Those percentages of the two scientific literacy domains are categorized as very low achievement (Srihanaty et al., 2022). The newly developed scientific literacy skills assessment also aligns with the PISA result. The newly developed scientific literacy skills show that most middle school students achieve low levels of scientific literacy. The scientific literacy component result shows that the comparison between school accreditation A and school accreditation B is a higher average of 46.98% than school accreditation B at 43.78%. Those indicate that scientific literacy skills among Indonesian students are relatively low (Rachmatullah et al., 2016).

The low scientific literacy score among Indonesian students has various reasons. The reason for the Indonesian PISA result is the ability of the students to analyze the text still poor which shows 31.34 from range of 0 to 100. It assumed that teachers' ability to support learning in the classroom has a significant impact on students' capacity to answer scientific problems (Adnan et al., 2021). The concept category in Indonesian students shows the "Not Understanding" category where students answer false in the first and second stages and the "Mistaken" category with students answer false in the first stage, but correct in the second. The "Not Understanding" shows 27.80% and the "Mistaken" shows 37.50% in the identification of scientific literacy (Indana et al., 2018). The low scientific literacy results are also affected by school science teachers. One of the problems that the teachers face is teaching science such as they have difficulty in teaching integrated science because they are mastering only in biology, but not chemistry or physics and vice versa (Rubini et al., 2016).

Literature Review

Wen et al. (2020) investigated the quality of the inquiry process, scientific literacy, and school science achievement should be used to evaluate students' performance. This finding demonstrates that guided inquiry has a greater beneficial impact on scientific literacy than open inquiry (Kang, 2022). The scientific literacy has been studied to find the connection with the scientific process skills (Kaya et al., 2012). other research examines the connection between elementary school students' scientific process skills and their degrees of scientific literacy (Jufrida et al., 2019). Another research examines the connection between the Science Technology Society and approach, scientific literacy (SL), and biological achievement (Mbajiorgu & Ali, 2003).

Conscious processing influences logical thinking, and when conscious processing is preoccupied, the result of logical thinking is worse (DeWall et al., 2008). Logical thinking also shows the connection into role-taking and moral reasoning. There was evidence that, in terms of developmental sequence, logical thinking comes before role-taking, and role-taking comes before moral reasoning at matching levels of conceptual complexity. Consolidated concrete operational thinking was correlated with Kohlberg's Stage 2 moral reasoning. Even though many received good marks for logical reasoning, they demonstrated cohesive, practical operational thinking (Smith, 1978). In biology courses, logical thinking correlates with the concept mastery questions, and the correlation between the two is moderate (Juhanda et al., 2020). Logical thinking contributes to mathematics learning in primary school, showing that students progress in learning mathematics after training in logical thinking rather than the group that does not get trained (Nunes et al., 2007). In other mathematics learning, a positive indication shows between logical thinking and interpreting the line graphic rather than students who do not possess logical thinking (Berg & Phillips, 1994).

Scoring on students' science achievement is also essential. Science achievement might relate to their interest in learning science. If the students are interested in learning science, their attitude and achievement toward science will be high, and vice versa. This is also supported by Jiang et al. (2015) that students' inquiry ability positively impacts measuring their interest in and attitude toward science. The factor related to science achievement is in analysing the reading skills and science knowledge, which shows a moderate correlation (O'Reilly & McNamara, 2007). Also, science achievement is affected by factors unrelated to the school area. The findings by Chiu (2007), an analysis of 107,834 students from 41 countries, show that family status influences the students' science achievement. It shows that science achievement positively impacts the students who are linked to high socioeconomic status, live with two parents, have more books, and have more cultural possessions and communication at home. Also, students' science achievement has a positive impact on the countries that have large amounts of incomes.

However, there is a gap in all the reviewed research, which reveals that no research explores the correlation between students' scientific literacy, logical thinking, and science score achievement. Therefore, this research filled the gap by exploring the correlation among them. By filling this gap, it might be valuable insight for educators and policymakers to enhance science education outcomes to increase the quality of education. By revealing the three variables, the teaching and learning strategy can be developed, and policymakers can design and develop an effective curriculum to improve and support students' cognitive development.

Many studies evaluate students' scientific literacy and aim to enhance their learning processes but often overlook their ability to think logically. This study seeks to bridge this gap by correlating scientific literacy scores, assessed through a test of logical thinking, with students' science achievement reflected in their academic reports. It explores the students' results in scientific literacy, logical thinking, and science achievement, examines how these elements interrelate, and investigates the factors that influence their correlation.

Method

This research design used an explanatory sequential design (Creswell, 2012). This research design is suitable to take the quantitative data by analyzing the quantitative data and continue by analyzing the qualitative data to get deeper information regarding the result of the quantitative data (Fraenkel et al., 2017), which is suitable for identifying relationships among variables without manipulating them. This research design also explores the connection between students' scientific literacy, logical thinking ability, and science achievement in school. Then, the reason for those connections will be connected by qualitative, in-depth interviews with the teacher regarding the learning activity and the scoring.

The data was collected from 92 Indonesian secondary school students of 15 year-old secondary school by the cross-sectional (Cresswell, 2012). The cross-sectional analysis provided the data at a specific time. This approach also allowed the researcher to assess the student's current condition regarding scientific literacy, logical thinking, and science score achievement. The sampling used convenience sampling (Golzar et al., 2022), to profile their scientific literacy (SL) that might be related to their logical thinking and their science score achievement. To simplify the flow of the study, the chart that represent the research flow shown in Figure 1.

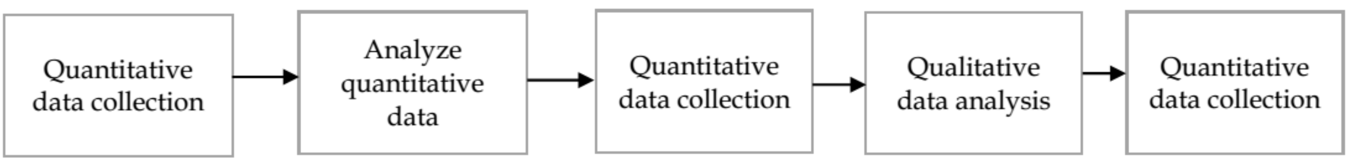

Figure 1. The flow of the research

Data Analysis

Scientific literacy test items in this research were used in the test items from PISA 2015 because scientific literacy is the dominant assessment in PISA 2015. The total number of TOLT test items is 10. Each of the components of the TOLT has two questions. Therefore, the TOLT score is categorized based on the correct answer. The competency in scientific literacy differs in each question from release items (OECD, 2015). The SL instrument was taken from PISA 2015 released items with some limitations of the competency not being exact for each. The purpose is to reveal the student's ability to conduct the scientific literacy test. This assessment has three competencies and different cognitive demands and difficulties. The scientific literacy test items used in this research were from the PISA 2015 released test items, which have limitations in the competency that are not equal.

Another variable, this research assessed the Logical Thinking Test, which has 10 questions with 5 reasoning types questions there are proportional reasoning, controlling variables, probabilistic reasoning, correlational reasoning, and combinatorial reasoning (Tobin & Capie, 1981). After assessing the students by the Test of Logical Thinking, the analysis is to find out about the number of students that can answer that reasoning type questions. Then, each question has several categories depending on whether the students ' answers are correct. According to Valanides (1997), in scoring the TOLT. If students have the correct answer for 0 – 1 item, it is categorized as concrete. If they have the correct answer for only 2 – 3 items, it is transitional; if it is correct for 4 – 10 items, it is formal reasoning. In the test of logical thinking, there are questions and the reason. Students must answer correctly in both of them to get one score. If the students have incorrect answers in one of them, the score is 0.

The next variable is the achievement of science scores. This research collects the science scores from the teacher. The purpose is to get accurate science scores. The science achievement scores in this research are the final scores in science subjects attached to their certificate.

After collecting three variables, this research used the Pearson Correlation Coefficient (r) by SPSS. according to Curtis (2004), using the Pearson Correlation Coefficient (r) requires both factors of the measurement scale to be interval or ratio data. The category of positive association has the two variables positively connected, meaning if one variable is increased, another is decreased. A negative association means if one variable is increased, another is decreased. Lastly, if the value is 0, means there are no correlation between them (Cooksey, 2020). The details of the correlation coefficient used to interpret the strength or weakness of the correlation are shown in Table 1.

Table 1. The Correlometer for Interpreting a Correlation Coefficient

Range	Interpretation	Category
+0.80 to +1.00	Very strong	Positive association
+0.60 to +0.79	Moderately strong	
+0.40 to +0.59	Moderate	
+0.20 to 0.39	Moderately weak	
+0.0 to 1.99	Weak	
0.0	No correlation	No association
-0.01 to -0.20	Weak	Negative association
-0.21 to -0.40	Moderately weak	
-0.41 to -0.60	Moderate	
-0.61 to -0.80	Moderately strong	
-0.81 to -1.00	Very strong	

In qualitative analysis, in-depth interviews were conducted to provide the details to support the quantitative research findings. The interviews focused on several possible criteria, such as the student's actual performance in science class, including practicum activity. The potential of the teachers to manipulate the score in students' reports in the interview is included because the result influences the quantitative one. Also, the Science Indonesia curriculum and the reality of conducting and implementing that curriculum demands in the classroom are analysed.

Result and Discussion

Students' Results of Scientific, Literacy, Logical Thinking, and Students' Science Achievement

Each of the SL and LT shows the percentage of each question and calculates the average of the result. LT result is categorized based on the number of correct answers. In SSA, the scores are from the students in grade 7 to grade 9 that are attached to their graduation certificates. In this result, the SSA calculates the participants' average and counts the number of students that score whether the SSA is higher or lower than the average.

The first result shows the students' SL results based on three competencies from PISA 2015 released items. It also reveals the number of students' correct answers in percentage form, shown in Table 2.

Table 2. Students' Results of Scientific Literacy

Competency	Percentage (%)
Evaluate and Design Scientific Inquiry	45.65
Explain Phenomena Scientifically	29.48
Interpret Data and Evidence Scientifically	36.46

The sum of the percentages on those competencies is not 100%, as the percentages represent independent measures of students' proficiency in each aspect of scientific literacy. Each competency is analyzed separately, and the percentages reflect the proportion of students who demonstrate proficiency in each specific domain. Then, the students' results are categorized into their reasoning in LT. The amount of the category of the students' reasoning is shown in Table 3.

Table 3. Category Reasoning Among Students

Category	Students	Percentages
Concrete	59	64.13%
Transitional	30	32.61%
Formal	3	3.26%
Total	92	100%

Next, this research assesses the average science achievement score (SSA). The standard minimum score is 72. The score between males and females are separated. Therefore, Table 4 shows 92 students' SSA.

Table 4. SSA of Students

Category	Students	Average SSA
Male	50	81.66
Female	42	82.22
Total	92	81.90

Table 4 shows that the average female students perform better in SSA rather than males. However, in this SSA the lowest score is 72.11 and the highest score is 98. After the result of SL, LT, and SSA collected, then it analyzed the correlation among them.

Correlation between Students' Scientific Literacy, Logical Thinking, and Science Score Achievement

After revealing the results in each SL, LT, and SSA, this research explores the correlation of three variables: scientific literacy (SL), logical thinking (LT), and Science score achievement (SSA), to discuss research question 1. The correlation of the three variables was analyzed using the Pearson correlation. The result of the analyses is shown in Table 5.

Table 5. The Result of the Correlation Among Variables

		SL	LT	SSA
SL	Pearson Correlation	1	0.354**	0.237*
	Sig. (2-tailed)		0.000	0.023
	N	92	92	92
LT	Pearson Correlation	0.354**	1	0.293**
	Sig. (2-tailed)	0.001		0.005
	N	92	92	92
SSA	Pearson Correlation	0.237*	0.293**	1
	Sig. (2-tailed)	0.023	0.005	
	N	92	92	92

From those results of the correlation between the SL, LT, and SSA discussed in each correlation. The correlation between SL and LT shows the Pearson Correlation value is 0.384. Also, the correlation between SL to SSA is 0.237, and LT to SSA is 0.290. This means the correlation among the data is moderately weak based on the correlometer. Even though the correlation is moderately weak, it shows a positive correlation. This means that each of the three variables shows that if the score in one variable increases, the other variable will also increase. The range of the score is from 0 to 100, as shown in Table 6.

Table 6. Detail of the Score in Some Samples

Student's initial	SL	LT	SSA
23M	15	20	74.56
1M	40	0	72.11
2M	40	10	75.78
7M	20	0	79.56
41M	75	60	80.33
29F	50	20	86.67
34F	35	30	83.44
47M	40	0	90.33
40F	75	20	87.11
48M	65	70	92.8

Table 6 illustrated that students with low SL also tend to have low LT scores and SSA and vice versa. For example, if the result of LT is in the "Formal" category, then the result of the SL and SSA is above average. Student 41M has the "Formal" category in LT. His results are in line with the SL result, but the SSA of that student is below the average. Another student in 48M has a high SSA. The "Formal" category can prove it and is in line with the score of the SL, which is good. Students 7M and 1M are the "Concrete" LT students with poor SL scores and SSA results. The findings are the same as those of student 23M, who found that "Transitional" has the SL and SSA below the students' average. However, the findings show that they are not always proportional to those variables that make that correlation positive, moderate, or weak. It can be analyzed in students 29F, 34F, and 40F who have "Transitional" reasoning and low scores in SL except 40F, even though the SSA is above the average. Student 47M has "Concrete" reasoning and a low score in the SL, but that student has a high score in the SSA

Factors Influence the Correlation between Scientific Literacy, Logical Thinking, and Science Achievement

The ***competencies*** in this PISA 2015 are part of the inquiry skills. In Indonesian science teacher's textbooks, there is a demand for teachers to use inquiry methods to improve science process skills (Lestari et al., 2021). The science process skills in this source state that the inquiry method starts with observing, planning, and conducting experiments or trials, collecting data, and presenting and drawing conclusions from the experiment results. The nature of science is part of the learning outcomes in science subjects. According to Hardanie et al. (2021), the first chapter explains the nature of science taught in grade 7, including measurement and the scientific method. This chapter also explains the role of science in human daily life and the laboratory and how to think sequentially in science, illustrated in laboratory activity, which is part of science process skills. All of these steps in science process skills and the nature of science need lab activity to require all of those steps. However, based on interviews with science teachers, state in science subjects rarely conducts lab activities. Science teachers state that the tools and materials used in lab activities are broken, especially after the COVID-19 pandemic, with no teacher controlling the laboratory tools and materials. Also, there is a science teacher who is too comfortable teaching science only in the classroom because they state it is too complicated to conduct the tools and materials to prepare the lab activity when students are in grades 7 and grade 8. Therefore, the students only learn about the context of the science based on the textbook without conducting any lab activity, which influences the students' science process skills, which is low. This also influences students' low science process skills and poor understanding of the nature of science because teachers in grades 7 and 8 have not graduated from science education or are not even in the education field, which does not know pedagogy about learning science and possible to has a poor ability to pedagogical content knowledge.

The SSA of the school regulations is collected from assignments, participants in discussions, attendance, and assessments. Based on the curriculum demand, the evaluation of science subjects has several rubrics, such as their laboratory performance and ability to write a report. In the assessment aspect, there is peer assessment and self-assessment. This research collected the SSA from the final score attached to students' certification. There are a lot of things that influence the SSA. The science teacher's in-depth interview stated the SSA needs to be increased as the principal school instructed, even when the final score was not as expected. The purpose of enforcing the increase of the SSA is also the requirement of the "Kurikulum Merdeka," which states that no students failed in the subjects. Even though the learning outcome was not as expected. The time of the semester also will not be enough if the teacher restarts the same topics, and there is no guarantee the students will improve their scores if the topics are studied again. Another reason also, this research assessed the participants of grade 9, which they must register into senior high school. The senior high school demands that students have good scores on their certificates. So, all of the teachers that taught the subject need to increase the score to make the students successfully registered in senior high school. Therefore, the result of these three variables is positively correlated but moderately weak because in SSA teachers do not give the actual score in SSA.

This research also assessed the teacher's ability. Therefore, the teacher's SL and TOLT results are discussed as supporting the result. Many science teachers teach the students in the school. Also, not all of the science teachers are science education graduates. The teacher in this result is a grade 9 teacher from a biology education graduate. The teacher only had 9 correct answers. Most answers are correct, with 4 correct answers explaining phenomena scientifically and 5 correct answers interpreting data and evidence scientifically. Therefore, the SL score is low in category 45. Nevertheless, the science teacher's result is still higher than the average of the students. However, if it compares to the highest score of a student, 41M, in Table 5, there is a significant difference between them. A teacher also assessed the reasoning using TOLT. The result shows that teachers had only two correct answers in proportional reasoning and combinatorial reasoning; therefore, the result of their reasoning category is transitional.

In science textbooks, both students' textbooks and teacher guidance support and lead the students to conduct inquiry-based learning. The students' textbooks already provide the experiment as a reference for the teacher to support science learning, and the students themselves can prove the result of the experiments. Then, the information regarding science topics can supported. The types of inquiry in students' textbooks do not contain the complete steps of the inquiry, that in order like ask about the phenomenon, designing the investigation, conducting an investigation, analyzing data, writing a conclusion, and communication (Widodo, 2021). However, the student's science textbook only requires several steps of inquiry. For example, the textbook provides the steps of the experiment, and students only fill in the results of their experiment and answer the questions provided and students' do not have opportunity to construct their own scientific questions.

Discussion

"Evaluate and Design Scientific Inquiry" competency is critically assessing scientific reports and investigations. Also, students need to be able to differentiate between scientific questions and other types of inquiry which identify a question to explore the scientific context (OECD, 2017). Inquiry begins when students encounter confusion about a phenomenon. Then, students conduct experiments to test their hypothesis. This inquiry process involves all of the activities that scientists do to collect information, such as hypothesizing, predicting, reading, planning, conducting experiments, and collaborating with other scientists (Rustaman, 2005). Unlike other learning models, inquiry learning is the most effective way to enhance the learning outcome. It is because, in inquiry learning, students get the opportunity to construct their own knowledge and connect to new information by their own cognitive structure to get meaningful learning (Andrini, 2016). The result of this competency shows 45.65% of students has correct answers, it means the inquiry ability of students is still lacking. Align finding regarding the dominance of students disable to conduct the inquiry found that 68.7% (554 out of 720) and ability of students in design the investigation is scored 14.8 out of 27 in 240 students. It is because factor regarding the ability students of inquiry. The influence of the students in doing inquiry are from the interaction from grouping, kinds of task, context, and teacher's role (Park et al., 2011).

In the competency that requires students to "Explain Phenomena Scientifically." Students need to act like the scientists who explain phenomena by providing evidence and reasons to strengthen their argumentation and facilitate other scientists' understanding of the validity of their claims (McNeill & Krajcik, 2008). Due to the quality of the students in the ability to explain the phenomena is still lack, the students need to be instructed, which they claim in scientific explanations needs to be supported by evidence and reason (Sandoval & Millwood, 2005). Other solution to improving the ability of the students is in the innovative curriculum especially with the learning outcome that engage students to improve the ability of their argumentation regarding the phenomena by strengthening their evidence and reasoning (Mcneill, 2009). Students participate in scientific argumentation; they rely it on their previous experience and prior knowledge, and this process aids them in reinforcing their current understanding and advancing their grasp of scientific concepts (Aufschnaiter et al., 2007). This competency reveals the ability of the students to understand the concepts of science behind the phenomena that happen in the context of physics that have positive correlation to the scientific concept formation and students understanding in physics (Ogundeji et al., 2020).

On the other side of the students' understand the concepts, there a positive relation to the ability of students' explain scientific phenomena is relate into their scientific imagination and students scientific concept formation (Madu, 2020). In the chemistry context, Indonesian students' ability to explain scientifically is still poor, which indicates low concept mastery, and this relates to the poor epistemology of the students' learning process (Laliyo et al., 2023). The low ability of students in "Explain Phenomena Scientifically" is a challenge for teachers because to build the scientific explanation, teachers and students are often construct the phenomena explanation from basic understanding of science, the limitations of the empirical data access, and the wide range of the ideas about the natural world (Braaten & Windschitl, 2011). This aligns with the in-depth interview with the teacher, who stated that the student's ability to learn science is still lacking.

The competency of "Interpret Data and Evidence Scientifically" is to analyze and evaluate the scientific data, the claims, and arguments in various forms also derive suitable conclusions and demonstrate the ability (OECD, 2017). This competency is should be part of the inquiry learning because it still part of the syntax. Therefore, previous research regarding the interpreting data is linked with the experiments part. The example is the students' ability in design the experiment and interpret data is connect each other. Those ability are only occuring in the laboratory classroom situation, so that the ability of the analyze data and design the experiment is improved when the students have the experiences of laboratory activity in inquiry learning (Myers & Burgess, 2003). The example of the activity in interpret data in science are describe the diagram about the x and y axes which are connected, including the highest and lowest. And analyze and summarize the data and used this data to predict the potential increase or decrease of the trends (Hafiyusholeh et al., 2018). The lack of ability of students in interpreting experimental data shows the inconsistency on the results of the opinion other interpretations and decide the steps of the interpretation (Ryder & Leach, 2000).

Three competencies of scientific literacy in PISA, OECD are connected to science process skills (Rustaman, 2007). According to Rustaman (2007) the indicators that need to be emphasized in science process skills are observation, interpretation, classification, prediction, communication, hypothesis, planning the investigation, applying the concept or principle, and asking questions. Previous findings regarding scientific literacy correlations to science process skills in students can prove it. Scientific literacy has a very strong positive correlation to the science process skills (Kaya et al., 2012). This is in line with the report of the in-depth interview with a science teacher, which found that most students have low results in scientific literacy because they have low ability in science process skills. The students' low ability in science process skills is caused by the rarely or even never conducting laboratory activities such as experiments or observing phenomena, which leads them to a poor understanding of the nature of science. The strategy in improving scientific literacy is using the science process skills approach that shows the result of scientific literacy is increased significantly (Husna et al., 2022). Therefore, it is important in science learning to improve scientific literacy from the experience of science process skills because the indicators of science process skills are connected. The most convenient strategy to improve science process skills based on those indicators is to conduct a laboratory activity (science practicum), which needs to be facilitated by a teacher. Also, the test items have 0 correct answers because students are unfamiliar with the complex multiple-choice, which has correct answers in more than 1 answer.

Most students find it difficult to answer these questions in the TOLT results. The category result shows concrete reasoning as the dominant and the formal reasoning is the smallest percentage. This distribution suggests that most of the students in this research are still in an earlier stage of cognitive development. Based on Piaget's cognitive development theory, concrete reasoning should be intended for students aged 7-11. The reason the formal-aged students are still in concrete operational is students are not getting their meaningful learning in science from the facilitator as they need assistance to improve the meaningful learning such as first-hand experience to improve their process thinking skills that require discussion and ability of the observation (Trifone, 1991). Logical reasoning is important to gain meaningful learning, and both are connected and important for students to problem-solve (Cavallo, 1996). It is supported by other research that found the TOLT ability shows a correlation into the science process skills positively high (Ismail & Jusoh, 2001). It can be proven from the test items in comparing the ability of the students in primary, junior secondary, and senior secondary shows the students in the younger age group, which should be concrete operational fail to conduct the abstract tests rather than other seniors (Collis, 1971). Another comparison between concrete operation in students aged 8 to 10 and formal operation in students aged 15-18 was from the differences in their performances in hands-on engineering. The students in the concrete operations stage can think logically, but they have a poor ability to think more abstractly and rely more on trial and error when addressing problem-solving (Cerovac & Keane, 2024). The reasoning behind TOLT is important as an aspect of the science course. According to Yenilmez et al. (2005), proportional reasoning is important in science because it relates to understanding the derivation and function of science. Controlling variables, such as planning, implementing, and interpreting, is important for students in science courses. Correlational reasoning is important in science courses because it is a hypothesis formulation in the potential relationship between variables. Probabilistic reasoning is important for students to interpret the data from the results of the investigations, observations, or experiments. Last, combinatorial reasoning is conducting the alternative hypothesis to test the effect of selected variables on a responding variable.

Many things influence this result of SL and TL. The most common things happen because the instructor used the test of skills in interpreting data and scientific evidence in students worksheets, daily test, mid-term test, and final-term test is still poor (Deratama et al., 2022). Therefore, in future learning, Yenilmez et al. (2005) advice teachers must understand their students' reasoning abilities and tailor their lessons to match them. For instance, students who think concretely should be given instructional materials that offer direct experiences and practical problems. To foster meaningful learning, teachers should assist students in abstracting essential concepts, understanding their connections, and applying and integrating their knowledge across different subjects and real-life situations. Therefore, teachers should create a diverse learning environment that addresses individual differences in reasoning abilities, as insufficient formal reasoning skills among students are often associated with lower science achievement. Teachers also should be able to determine the misconceptions responses on students because teacher need to plan on the next learning activity (Schneider & Gowan, 2013).

In SSA, based on the interview with the science teacher, another science teacher sometimes gives a high score not intended for students with high scores in science subjects. Still, they give high scores in the report to diligent students with a good attitude, good attendance, and other things outside the students' abilities in science. Therefore, the correlation between the SL, LT, and SSA is biased because the SSA does not accurately score the students' cognitive ability. Also, the principal instructs that the student should be above the final score on the course above the standard minimum. Therefore, teachers should make a strategy such as giving additional assignments to fulfill the minimum score. Also, the Indonesian national curriculum (Kurikulum Merdeka) requires students to be promoted to the next grade level even though the students still have poor score or performance in the course. The score of science should come from the cognitive abilities such as science knowledge and reading skill because both of them are convenience predictors in measure science achievement score (O'Reilly & McNamara, 2007). The SL, LT, and SSA results influence by teacher quality. It is supported because the teacher quality characteristics shows the positive correlation into students output for example teachers qualifications, certifications and education level in the field that taught (Darling-Hammond, 2000). Effective learning also positively correlates with experienced teachers, but there is no evidence also for pre-service (undergraduate) teachers' ability to increase student achievement (Harris & Sass, 2011). Effective teachers scored higher in instruction, student assessments, classroom management, and personal qualities rather than ineffective teachers because effective teachers provide a learning strategy by using a variety of materials and media to support the curriculum output (Stronge et al., 2007). Experienced teachers can improve students' performance on tests, and experienced teachers are also able to control any class size and teachers should teach in earlier grades (Gerritsen et al., 2017). However, the interview session contradicts those findings between senior teachers and fresh-graduate teachers. The interview stated that the senior teachers are too comfortable teaching science only in classroom settings and comfortable not taking hands-on activity in the laboratory. Also, senior teachers always rely on junior teachers in any kind of task or instruction, even if the junior teachers have poor experiences. However, the students' science textbooks provided a worksheet and an experiment, which required inquiry learning and enhanced their science process skills. Also, the learning objectives are completed at the low cognitive level, such as memorizing, until the high cognitive level, such as analyzing and applying.

This research aligns with previous findings regarding the correlation between scientific literacy, science achievement, and logical thinking that can robust the findings. Scientific literacy positively correlates to science learning achievement among Indonesian secondary school students. However, both of the scores is in low category (Jufrida et al., 2019). Another positive correlation to scientific literacy skills among Indonesian students is students' achievement motivation, critical thinking skills, and reading comprehension (Wahyuni et al., 2018). It can be shown that students with high critical thinking skills can understand literacy because students use their prior knowledge in their reasoning skills. Another correlation between scientific literacy and critical thinking is positive because critical thinking indicates students' understanding in a science course (Listiani et al., 2022). Another positive relation in scientific literacy is related to the ability of students' higher-order thinking skills because the indicators between two of them connected each other, such as identifying and evaluating problems, analyzing and interpreting data, and solving the problem (Arifiyyati et al., 2023). Scientific literacy also has a correlation in moderate low positive to the science interest of the students (Fadila et al., 2020). Proportional reasoning has relation between mathematics and science course. According to Dole et al. (2012), proportional reasoning in science includes calculations such as calculating density, molarity, speed, acceleration, force, and others that need that competence to give the ratio and proportion. Understanding ratios and proportions make applying rules and formulas easier and manipulating the numbers and symbols in equations. The students with high proportional reasoning have high scores on SL and SSA. This is inline with the Mardika et al. (2021) that shows the students in high achievement classes have moderate proportional reasoning ability, and those in low achievement classes have difficulties answering the proportional reasoning questions, resulting in low scores.

The result of the SL, TOLT, and achievement must be provided by good education. The quality of education is supported by several policies, such as providing educational resources such as libraries and laboratory equipment. Also, a teacher's commitment to education is important and influences the students' performance as the facilitator (Santos, 2007). In laboratory learning, there are positive effects to the students in their attitude, and it also influences their knowledge achievement (Freedman, 1997).

Conclusion

The average SL score was relatively low at 33.04%. For TOLT, 64.13% of students exhibited concrete reasoning, 32.61% showed proportional reasoning, and 3.26% demonstrated formal reasoning. SSA scores averaged 81.90, with 53 students achieving above-average results. It implies to the correlation between SL, TOLT, and SSA was positive but moderately weak. SSA scores averaged 81.90, with 53 students achieving above-average results. Teacher interviews revealed that the low SL and LT scores stemmed from limited hands-on activities in the classroom, as teaching heavily relied on lectures. Additionally, science textbooks lacked inquiry-based learning tasks. The implications of this research are about teaching strategies that should provided to improve scientific literacy scores and new strategies to diagnose the phase of the cognitive development of the students before applying the learning to aim for meaningful learning and consider the science achievement not to manipulate the score in students' semester report. The limitations of this research are that it does not compare genders, school curriculums, or school locations, whether urban or suburban. The psychological aspects regarding the students' interest or efficacy are not included in the discussion or provided. This research has no empirical proof that students with positive learning experiences in science have good results in SL and TOLT. Therefore, future research should apply LT's next PISA-released items in the mathematics domain and connect them. The participants can compare the students between public and private schools, which are different in any way, such as the facilitate, teacher quality, socio-economic levels, etc.

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