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# Scientific Reasoning Ability of High School Students in Palangka Raya in Physics Learning

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**ABSTRACT**

**Purpose-**Scientific reasoning is an essential ability in learning science, including physics. This study aims to assess the scientific reasoning abilities of high school students in Palangka Raya City, focusing on six indicators: conservation reasoning, proportional reasoning, variable control, probabilistic reasoning, correlation reasoning, and hypothetical-deductive reasoning.

**Methodology**-To achieve the goals, descriptive research consisted of 187 samples from six schools in two districts using the multistage stratified random sampling method. The instrument used in this study is Lawson's Classroom Test of Scientific Reasoning (LCTSR), containing twelve multiple-choice items. The data were analyzed using the Kruskal-Wallis test to determine the differences in average scores between schools, and descriptive statistics were used to describe students' general scientific reasoning skills. The analysis results show a p-value of 0.001, indicating that the test detected a statistically significant difference in the average score of scientific reasoning ability among high school students in the sample schools in Palangka Raya City.

**Findings**-The descriptive analysis results showed that the conservation reasoning indicator had the highest percentage of correctness, while hypothetical-deductive reasoning was the least mastered by students. Additionally, most students are in the concrete operational thinking phase, despite having theoretically reached the formal operational phase in terms of cognitive development.

**Contribution-**This finding has implications for educators in designing physics learning strategies that encourage the development of students' scientific reasoning as they progress toward the formal operational phase.

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## INTRODUCTION

Physics is a field of science that studies the laws that govern how the universe works, from celestial bodies to atomic-scale particles. Physicists discovered these laws through systematic scientific research (Novitasari & Mediatati, 2021). In physics, physicists need various methods, tools, and materials to conduct experiments and collect accurate data (Lestari et al., 2018; Murdani, 2020). In addition to using hardware and software, physicists need strong cognitive skills in designing experiments, controlling their implementation, and processing data collection results (Labouta et al., 2018; Suna Ryu et al., 2018). Among the various thinking skills required in scientific research, the ability to reason scientifically is one of the most important in helping physicists understand and explain natural phenomena logically and based on evidence (Osborne, 2018). In the context of education, a deep understanding of physics concepts can only be achieved if students can develop scientific reasoning skills, which allow them to think critically and logically about various physical phenomena (Erlina et al., 2016; Wilujeng & Wibowo, 2021).

Piaget explains the ability to think and reason of human beings through his cognitive development theory. According to Piaget, toddlers can only think and reason based on what their five senses receive because they are still in the pre-operational phase (de Ribaupierre, 2015). When children enter the elementary school age, they begin to think operationally. However, their reasoning is still limited to concrete and contextual matters, as is characteristic of the concrete operational phase (Pakpahan, 2022). After that, children will enter the formal operational phase, characterized by the ability to understand and describe various abstract concepts (Levitt et al., 2017). In this formal operational phase, students' scientific reasoning abilities develop, allowing them to analyze and synthesize information more in-depth and abstractly (Han, 2013). Although students can understand simple cause-and-effect relationships in the concrete operational phase, they still face difficulties processing abstract concepts often encountered in physics, such as force or energy (Ozkan & Topsakal, 2020). Meanwhile, in the formal operational phase, students' ability to think abstractly and logically enables them to solve more complex scientific problems, including experiments involving variables that are not directly observable.

Experts have developed various definitions of scientific reasoning. Linn (1982) explained that scientific reasoning uses scientific knowledge and inquiry methods to understand natural phenomena. Osborne (2018) emphasized that the ultimate goal of scientific reasoning is understanding the laws of nature. In line with Lawson, Zimmerman (2005) also highlights the importance of scientific reasoning in the scientific method, but with a broader focus on problem-solving. According to Zimmerman, scientific reasoning aspects are understanding, identifying, and using scientific methods to solve problems. Lawson (2004) presents a more detailed definition, explaining that scientific reasoning is the ability to construct and evaluate arguments based on empirical evidence, propose testable predictions, and use deductive and inductive logic to evaluate experiments. Although Osborne and Zimmerman's definitions emphasize aspects of understanding natural law and problem-solving, Lawson provides a more specific definition by including prediction testing and deductive and inductive logic. This indicates that scientific reasoning is closely tied to the results and methods of thinking employed in scientific processes.

Scientific reasoning has a vital role in physics learning. As a science that relies on empirical evidence, physics helps students understand its concepts through experiments, hypothesis preparation, data collection, and drawing conclusions based on existing evidence (Girwidz et al., 2021; Puspitasari, 2022). The process reflects the essential scientific method in scientific reasoning, where students analyse situations, solve problems based on evidence, and understand the relationships between variables in physical phenomena (Abdullaeva et al., 2020). Furthermore, scientific reasoning is crucial in actual experiments and thought experiments (gedanken experiments), as Einstein used in his theory of relativity. The mind experiment allows the simulation of physical phenomena in the mind and can only be executed with strong scientific reasoning.

Low scientific reasoning ability can have various negative consequences in learning activities, especially in physics. Students who have not developed this ability will find it challenging to build an understanding of cause-and-effect relationships between variables, are unable to interpret experimental results logically, and tend to memorize formulas rather than understand their conceptual meaning. Identical characteristics were found in several high schools in Palangka Raya city. The researcher's observations revealed that some students tended to be passive in practicum activities because they lacked the framework to design experiments, collect data, evaluate the data, and draw conclusions. This condition hinders critical and creative thinking skills, limiting the ability to solve problems independently. In the long term, students who do not develop scientific reasoning optimally will struggle to build advanced physics concepts that require logical and abstract reasoning. Ultimately, these issues have the potential to diminish students' interest and motivation in learning physics.

Mapping and measuring scientific reasoning ability are requirements in the planning and implementation of Physics learning. This measurement is used to determine the level of reasoning that aligns with students' cognitive development, as well as to identify aspects of reasoning that require pedagogical intervention. Without this data, teachers will struggle to differentiate effective learning, such as determining appropriate approaches, models, and strategies, and to strengthen high-level thinking skills.

A valid and reliable instrument is required to measure scientific reasoning accurately. One of the most used instruments to measure the ability is Lawson's Classroom Test of Scientific Reasoning (LCTSR), developed by Lawson (2004). This instrument measures six indicators of scientific reasoning ability, namely conservation reasoning (the ability to understand changes in concepts), proportional reasoning (the ability to compare quantitative relationships), variable control (the ability to identify the actions of free and bound variables), probabilistic reasoning (the ability to assess the likelihood of an event occurring), correlation reasoning (the ability to see the relationship between two variables), and hypothesis-deductive reasoning (the ability to conclude the statement submitted). Each indicator has distinct characteristics, so the construction of its measurement items in LCTSR also varies accordingly. This instrument has been validated and proven reliable through various studies, making it a widely used tool for assessing students' scientific reasoning (Bao et al., 2018; Han, 2013).

Nagara et al. (2019) used LCTSR in secondary schools in Indonesia. He found that most students are still at the stage of concrete operational reasoning and have not yet achieved higher formal operational reasoning. Furthermore, Aini et al. (2018) identified the scientific reasoning ability of high school students in Jember. They found that students still face difficulties in certain aspects, especially in variable control and probabilistic reasoning. On the other hand, Handayani et al. (2020) mapped the scientific reasoning ability of students in Sukabumi. They found that students there had difficulties in more abstract aspects, such as probabilistic and correlational reasoning. These studies have successfully identified aspects of scientific reasoning that students need to improve.

Previous studies have identified and reviewed students' levels of scientific reasoning. However, their discussions focused on scientific reasoning skills in general. In contrast to previous studies, this study specifically focuses on scientific reasoning in Physics learning, because these skills are necessary for students to develop a comprehensive understanding of Physics. Additionally, this is the first study conducted in Central Kalimantan Province using Lawson's Classroom Test of Scientific Reasoning (LCTSR) instrument to assess six indicators of scientific reasoning.

Lawson's Classroom Test of Scientific Reasoning, an instrument that has been tested, will be used to measure students' abilities. This instrument measures the six indicators of scientific reasoning presented: conservation reasoning, proportional reasoning, variable control, probabilistic reasoning, correlational reasoning, and hypothetical-deductive reasoning. The mapping results are expected to provide helpful information for educators, especially physics teachers, to design learning that meets their needs and students' cognitive development level in scientific reasoning skills. Additionally, this mapping will help identify aspects of scientific reasoning that require reinforcement, allowing for improvement through a more structured learning approach.

Based on this background, this study focused on mapping students' scientific reasoning abilities in learning Physics using Lawson's Classroom Test of Scientific Reasoning (LCTSR) instrument. To that aim, this study was designed to answer the following questions:

a. How is the level of scientific reasoning ability of high school students in Central Kalimantan in the context of Physics learning based on six LCTSR indicators?

b. What are the indicators of scientific reasoning that students in learning Physics most and least master?

## METHODOLOGY

### Research Design

This descriptive research study aims to map and describe a phenomenon using scientific methods and measuring tools. In this context, the phenomenon being studied is the scientific reasoning ability of high school students in Palangka Raya City, specifically in relation to physics materials. All grade 12 students in the city of Palangka Raya formed the study population. The selection of grade XII is based on the scope of the material that has been studied. Grade XII students have certainly studied more and deeper physics material than grade X or XI students. Besides, another consideration in choosing samples is related to cognitive development aspects, where the learning processes experienced by grade XII students must have enhanced their ability to think abstractly. Physics topics, such as thermodynamics and optical physics, require students to construct imaginary molecules or processes from daily scientific phenomena.

### Smaples

The research samples were selected using a multistage stratified random sampling method. There are three stages of sample selection. In the first stage, the researcher randomly selected two of the five districts in Palangka Raya City, specifically Pahandut and Jekan Raya. Next, the sample schools were chosen from each district, where Pahandut and Jekan Raya districts have 17 and 14 high schools, respectively. Three high schools, both public and private, were selected from each of them. In the final stage, the researcher selected a research sample class from each school. One class is randomly selected from all 12th-grade science classes in each school. A total of 187 respondents participated in this study. The details of the selected sample are presented in Table 1 below.

**Table 1**. Sample distribution

| District | Schools | Status | Sample Class | Students |
|---|---|---|---|---|
| Pahandut | High School A | Public | XII MIPA-2 | 36 |
| | High School B | Public | XII MIPA-2 | 36 |
| | High School C | Private | XII MIPA | 33 |
| Jekan Raya | High School D | Public | XII MIPA-6 | 27 |
| | High School E | Public | XII MIPA-3 | 36 |
| | High School F | Private | XII MIPA | 19 |
| Total | | | | 187 |

The research instruments used in this study are adapted from the Lawson Classroom Test of Scientific Reasoning (Lawson, 2004), which includes physics concepts. The original LCTSR instrument was translated into Indonesian to make it suitable for students. The scientific reasoning indicators used for this measurement are conservation reasoning, proportional reasoning, variable control, probabilistic reasoning, correlation reasoning, and hypothesis-deductive reasoning. Each item in the instrument is in the form of a two-tier test. The first level is students' response to a case or phenomenon, while the second level is the reasoning behind that response. The construction of this item is expected to provide an in-depth measurement of scientific reasoning ability. Details of the instrument construction are presented in Table 2.

The scientific reasoning instrument used in this study consists of 12 measurement items, similar to the original one. Those adapted items were checked and validated by five experts to determine their content validity. The experts' task was to determine whether the adapted items met the content criteria set by the LCTSR original instrument. Using Aiken's V equation, the validity score for the adapted instruments is 0,93, which is valid and ready to be utilized. The mass try-out test was not necessary since the original instrument had already been obtained.

**Table 2**. Scientific reasoning instrumentation

| Item | Indicators | Measurement Detail |
|---|---|---|
| 1 | Weight Conservation | Determining the mass of two clays of the same material and mass, but having different shapes. |
| 2 | Volume Conservation | Comparing the rise in water level of two identical measuring cups when two balls with different masses but the same volume are inserted |
| 3, 4 | Proportional Reasoning | Determining the water level that will be read if the water that was initially in the large measuring cup is poured into the small measuring cup |
| 5 | Variable Control | Designing an experiment to test the effect of the length of the pendulum string on its swing period. |
| 6, 7 | Variable Control | Analyzing the response data of fruit flies in cylinders to determine the influence of Light and gravity on the behavior of flies |
| 8, 9 | Probability Reasoning | Predicting the chances of picking up an object of a particular color from a bag |
| 10 | Correlational Reasoning | Predicting the relationship between the large angle of the inclined plane and the force required to raise the load |
| 11 | Hypothesis-Deductive Reasoning | Designing an experiment to determine why water is pushed into the glass after the candle has been extinguished. |
| 12 | Hypothesis-Deductive Reasoning | Designing experiments to determine why red blood cells shrink after the addition of salt droplets |

Each instrument's item requires respondents to select an answer and provide a corresponding reason related to a phenomenon. Scientific reasoning can occur when a respondent can choose a good answer based on scientific considerations. Respondents only receive a score when they select the correct answer and provide a corresponding reason (Bao et al., 2018). If one of them is wrong, it can be said that the respondents cannot make scientific reasoning, so no score is obtained. With a maximum of 12 items, the maximum score that respondents can obtain is 12, and the minimum score is 0. Details of the item scoring techniques are presented in Table 3 below.

**Table 3**. Scoring of scientific reasoning item

| Infomation | Score |
|---|---|
| Correct answer and correct reason | 1 |
| Correct answer and wrong reason | 0 |
| Wrong answer and correct reason | 0 |
| Wrong answer and wrong reason | 0 |

Scientific reasoning scores between schools can be compared to determine if there is a gap in scientific reasoning ability among the sample schools. Inferential statistical analysis was conducted to identify the gap. The analysis begins with a normality test using the Shapiro-Wilk test, which is performed with the help of JASP software. If the data are normally distributed, the analysis is carried out using parametric statistics, specifically ANOVA, to determine the mean difference between the sample groups. However, if the data are abnormally distributed, the analysis proceeds with non-parametric statistics, specifically the Kruskal-Wallis test.

Furthermore, the researcher also analyzed the accuracy of the respondents' answers in each school. Using equation (1), the percentage of students who answer a question correctly can be determined. This analysis will be conducted on all six of Lawson's scientific reasoning indicators. This method can generate a scientific reasoning profile for each school for each scientific reasoning indicator:

$$Correct\ students\ percentage = \frac{Number\ of\ correct\ students}{/Total\ respondents}\ x\ 100\%$$

Additionally, the researcher categorized each respondent's scientific reasoning. The scoring results are the basis for determining the category of scientific reasoning. The categorization in this study is based on Han (2013), as described in Table 4 below.

**Table 4**. Category of scientific reasoning ability

| Score | Category |
|---|---|
| 9 – 12 | Formal |
| 5 – 8 | Transition |
| 0 – 4 | Concrete |

**FINDINGS**

A normality test was conducted on the scientific reasoning scores of all respondents to determine the distribution pattern of the data obtained. Since the number of responses was 187, the type of test used was the Shapiro-Wilk test through the JASP program. The results obtained are shown in Table 5 below. The p-value obtained from the Shapiro-Wilk test is 0.001, which is less than 0.05. This shows that the distribution of scientific reasoning score data is abnormal. Therefore, the mean difference test is continued with non-parametric statistics.

**Table 5**. Shapiro-Wilk Test

| | Score |
|---|---|
| Valid | 187 |
| Shapiro-Wilk | 0.886 |
| P-value of Shapiro-Wilk | < 0.001 |
| Minimum | 0.00 |
| Maximum | 10.00 |

Non-parametric statistics have several types of mean difference tests. The choice of test used depends on the number of groups and the variability between groups. Because six groups of samples were tested for the difference in average, the type of test used was the Kruskal-Wallis test. The analysis of group variance was conducted using the JASP program, and the results of the score description are presented in Table 6 below. The table displays the Coefficient of Variation (CV) values for each sample group. It can be seen that the CV value falls within the farthest range of 0.65–0.94. This value range can be tolerated by the Kruskal-Wallis test regarding homogeneity between sample groups, allowing the test to be conducted.

**Table 6**. Description of Coefficient of Variation

| Schools | N | Mean | Std Dev. | Coefficient of Variation |
|---|---|---|---|---|
| High School A | 36 | 2.028 | 1.812 | 0.894 |
| High School B | 36 | 3.222 | 2.113 | 0.656 |
| High School C | 33 | 2.970 | 2.008 | 0.676 |
| High School D | 27 | 1.667 | 1.569 | 0.941 |
| High School E | 36 | 2.861 | 2.368 | 0.828 |
| High School F | 19 | 1.263 | 1.147 | 0.908 |

**Table 7**. Kruskal-Wallis Test

| Factor | Statistic | df | p |
|---|---|---|---|
| School | 20.798 | 5 | < 0.001 |

Furthermore, the Kruskal-Wallis Test was conducted using the JASP program, and the results are presented in Table 7. The table displays a p-value of 0.001, which is less than 0.05. This means that the Kruskal-Wallis test detected a difference in the average score of scientific reasoning ability of high school students in sample schools in Palangka Raya City. The differences in students' scientific reasoning abilities are explained in more detail through descriptive analysis of the percentage of students who answered correctly in each school. The percentage of correct answers of students in each school for each scientific reasoning indicator is shown in Figure 1. The figure shows the variation in scientific reasoning ability between schools. Generally, no school has a percentage of students who answer scientific reasoning questions correctly above 70%. The highest percentage is 67 percent, and the lowest is 3%.

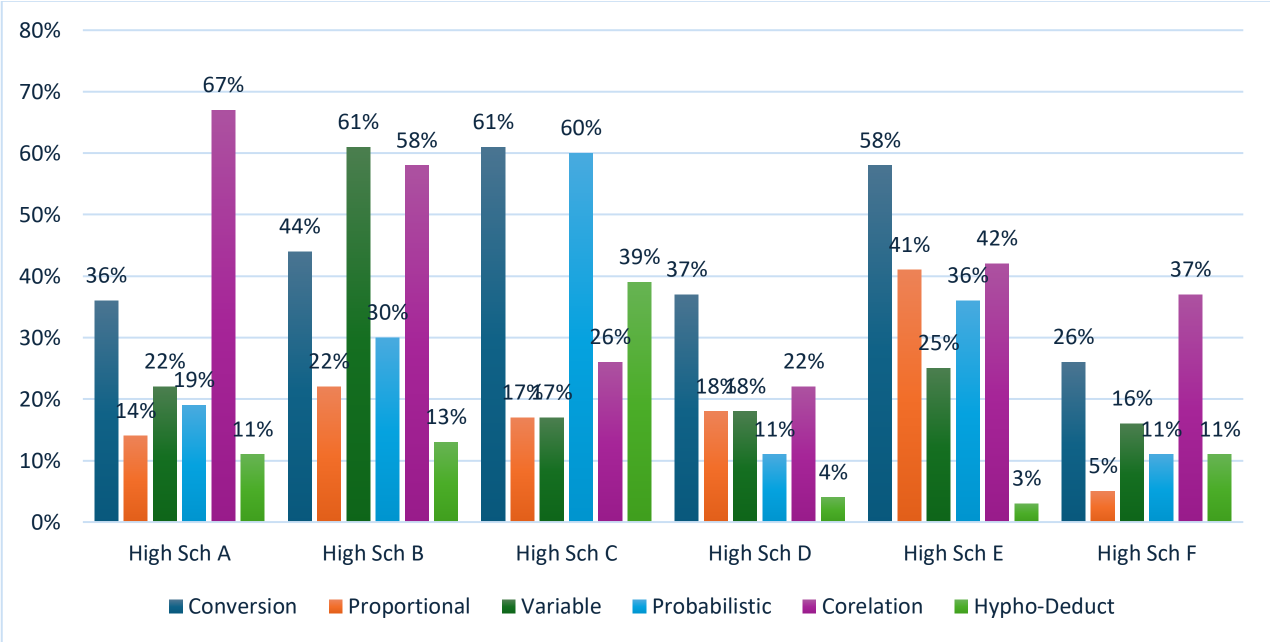


**Figure 1**. Percentage of correct answers in each school

Figure 1 provides information on each school's highest and lowest aspects of scientific reasoning. High School A has strength in correlation and conservation reasoning indicators, but is weak in proportional and hypothesis-deductive reasoning. High School B is strong in variable control indicators and correlation reasoning, but also weak in proportional and hypothesis-deductive reasoning. High School C excels in conservation reasoning indicators and probabilistic reasoning but is weak in proportional reasoning and variable control. Furthermore, High School D is stronger on conservation reasoning indicators and weaker on deductive hypothesis reasoning. High School E is strong in the aspects of conservation, proportional, and correlation reasoning, but is weak in the aspects of hypothetical-deductive reasoning. Finally, High School F is stronger in correlation reasoning and weaker in proportional reasoning.

In general, the indicator that is most correctly answered by students is conservation reasoning. This indicator is ranked first in High School C, High School D, and High School E. It also ranks second in High School A and F, and third in High School B. The next highest indicator with the most correct answers is conservation reasoning. The percentage of this indicator even reached the highest overall, at 67%. Then, some indicators have a high percentage in only one school but a low percentage in another. The indicators of such anomalies are variable control and probabilistic reasoning. Some schools do have differences in the highest percentage of scientific reasoning indicators. However, these schools have the same scientific reasoning indicators with the lowest percentage: hypothetical-deductive reasoning, correlation, and proportional reasoning.

## DISCUSSION

Conservation reasoning is the reasoning used to understand that even though something has a changed appearance, it is still the same amount. This ability is measured by two questions about mass conservation and volume conservation, which ask respondents to make inferences based on the concepts of mass and volume that they have learned. The item on mass conservation presents two clay balls that have identical masses. One of the pieces of land was then crushed, and respondents were asked to compare the masses of the two. Students who still use concrete reasoning tend to compare things based on appearance (Osborne, 2018). Some students think that when clay is crushed, the mass increases. Vice versa, some students think the mass decreases when it is crushed. Mass is related to the amount of matter that a substance has. The mass will always be the same when no substance is added to the clay, regardless of shape.

LCTSR items for volume conservation are shown in Figure 2. The item presents two balls, each dipped in a separate tube containing the same volume of water. The two balls have the same volume, but their masses differ because they are composed of different materials. Respondents were asked to predict the rise in water when the two balls were submerged in each tube and the reason. The concept used in this item is the effect of adding the outer volume to the volume of water in the tube. Since both balls have the same volume, the water volume displacement is the same. If respondents can provide a reason for this, then they can immediately determine that the water in both tubes will be the same height after both balls are submerged. Mass is not part of the volume variable, so it will not affect the increase in water level.

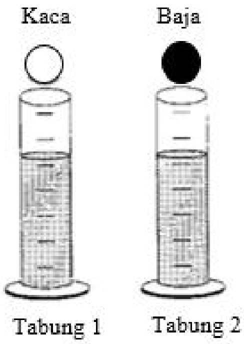


**Figure 2**. Volume conservation

The conservation reasoning indicators have a higher percentage of correct responses than other indicators. However, out of six schools, only two achieved a correct percentage of more than 50%, which are High Schools C and E. This means more than half of the respondents could not answer these two questions correctly. In physics lessons, the concept of mass is the earliest topic taught in class X. If respondents cannot answer this item correctly, they do not have a complete concept of mass. Furthermore, for volume conservation, this item relates to Archimedes' Law, which states that the volume of a liquid displaced by an object is proportional to the volume of the object immersed in the liquid. Respondents who could not answer this item correctly had misconceptions about Archimedes' Law. This condition must be a special concern for educators designing physics learning on measurement and Archimedes' Law.

Proportional reasoning is understanding and utilizing equivalent comparisons in various contexts and situations. Through this ability, individuals can transfer the equivalence of comparisons from one situation to another, such as a two-dimensional representation to three dimensions, or from the scale of comparison on a map to the size of the real world. When the proportion between the real-world distance and the distance on the map is recognized, one can calculate the actual distance through the information on the map. In Physics, an example of proportional reasoning can be found in the concept of density, which connects the variables of mass and volume. The two variables exhibit a positive linear relationship, where the increase in volume corresponds to an increase in mass on the same scale. This ability is needed in scientific activities, especially when reading, sorting, and analyzing measurement data.

Proportional reasoning ability was assessed in this study using a volume comparison context. The measurement items involved a proportional comparison between two beakers of different sizes and scaling. Respondents were asked to infer a proportional relationship based on the information that a volume of water reads on scale 4 in the large beaker and scale 6 in the small beaker (Figure 3). The question is: if the water reads six on the scale in the large beaker, how many scales will it read in the small beaker? This item requires understanding the comparison principle, which emphasizes that the same object can show different measuring values depending on the tool and scale. This item tests respondents' ability to perform proportional transformations and recognize inequalities in the measurement system.

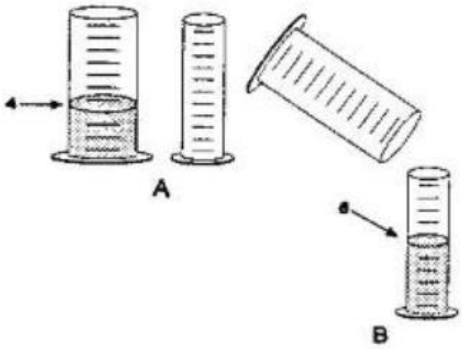


**Figure 3**. Proportional reasoning

The measurement results indicate that proportional reasoning is a challenging concept for most students. Only High School E achieved a correct percentage of 40%, while the other schools were in the range of 15-20%. This result indicates that students have a low mastery of the concept of equivalent comparison, which is the fundamental foundation of mathematical reasoning. Standard errors were due to students' inability to identify the proportional relation of measurement scales. The students used addition operations instead of multiplication to solve this question. The difference in scale between the two measuring cups was seen as a fixed value rather than a fixed ratio.

The variable control is a method used to identify and control variables during an experiment or activity. The item on variable control presents three pendulums with variable pendulum masses and string lengths (Figure 4). Pendulum 1 has a mass equivalent to that of pendulum 2. On the other hand, the length of pendulum 1 is identical to that of pendulum 3. Respondents were asked to determine the pendulum used in the experiment to investigate the effect of rope length on the period of pendulum swing. This item relates to respondents' ability to recognize manipulation and control variables, which are closely tied to scientific investigation activities. In experiments, the manipulation variable must be changed to determine its effect on the response variable.

On the other hand, the control variable must be kept constant to avoid any impact on the response variable. In the context of this item, the manipulation variable is the length of the string, the response variable is the swing period of the pendulum, and the control variable that must be kept constant is the pendulum's mass. Respondents must choose different pendulum string lengths and constant pendulum masses to determine the period.

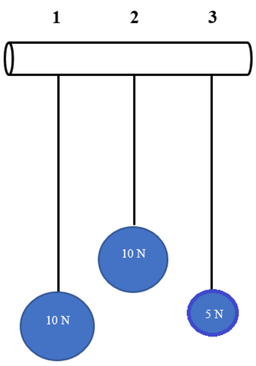


**Figure 4**. Controlling variable

An understanding of the types of investigation variables is built through experimental activities. (Zulkipli et al., 2020). Of the six schools, only High School B has a correct percentage of more than 50%. This means that most students from this school understand both the essence and the technical aspects of the scientific inquiry process. Scientific investigation activities aim to uncover the laws of nature. This process begins by asking questions about a strange natural phenomenon and continues with the design and experimentation. The other five schools should also take note of this aspect of physics learning. The science and concepts of physics are built through data obtained from scientific investigations. Students should not only follow predetermined procedures in experiments (Suma, 2010). However, more deeply, they must be invited to delve into the experimental process to discover the reason for selecting manipulation, response, and control variables from the experiment.

Probability reasoning involves the cognitive ability to evaluate the likelihood of an event occurring based on the principle of probability. This ability is crucial in scientific and everyday decision-making, especially when the information available is random or uncertain. This ability is measured through the concept of simple chance events. Ideally, students in the formal operational phase can distinguish things that are certain or possible to happen based on chance calculations. The item measuring this ability uses the context of randomly selecting a particular colored cube from a bag (Figure 5). The question then continues by adding other colors and shapes of objects. This question assesses the respondent's ability to translate concrete situations into mathematical representations of probability, particularly the phrase "or," which in probability refers to the combination of two or more events.

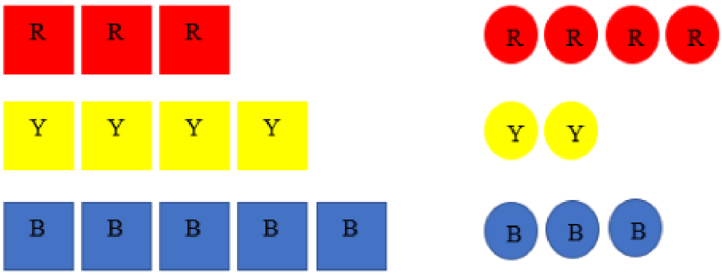


**Figure 5**. Probability reasoning

The results show that High School C has the highest correct percentage in probability reasoning, reaching 60% of the respondents. The next highest correct order belongs to High School B and E, with a percentage of 30%. Other than these three schools, the percentage obtained was below 20%. This finding suggests that most students continue to struggle with understanding and applying probability concepts, such as the distinction between dependent and independent events. Respondents tended to rely on guesses or associations of colors and shapes without calculating ratios appropriately. The differences between schools show variations in math and science learning, especially in logic and symbolic representation.

Correlational reasoning is identifying and understanding reciprocal and inverse relationships between variables. This ability is essential in physics because many physical concepts and laws contain variables that affect each other in a cause-and-effect relationship. For example, Ohm's Law states that Voltage is directly proportional to Electric current, as long as the resistance value remains fixed. Similarly, in Newton's Second Law, the acceleration of an object is affected by the force and mass of the object. Understanding the cause-and-effect relationships of various physics variables is necessary to form a complete physics concept. This ability is measured through questions about inclined planes, where respondents are asked to determine the relationship between the angle of the inclined plane and the thrust force needed to raise an object onto it. This question requires students to analyze how a change in one variable (angle) affects another variable (force) and whether the relationship is direct or inverse.

The results showed that High Schools A and B had a better percentage of correct answers for correlational reasoning, with around 60%. High Schools E and F followed this with around 40%, and C and D with around 20%. Compared to other aspects of scientific reasoning, the percentage of correct answers on correlational reasoning is relatively higher. This relatively high achievement indicates that physics learning in these schools has led to relational understanding between variables, although it may not be fully conceptualized.

A key area that requires serious attention is hypothetical-deductive reasoning. This ability involves determining the experiments necessary to test a hypothesis. This indicator measurement item presents a lit candle in a container filled with water (Figure 4). The candle is then covered with an empty glass until the flame is extinguished. At the same time, water from the container is sucked into the glass. This process gave rise to a hypothesis that "water is sucked in because the carbon dioxide in the glass dissolves into the water. The air pressure inside decreases, so that water from the outside enters the inside". Respondents were asked to determine the experiments needed to prove the truth of the hypothesis.

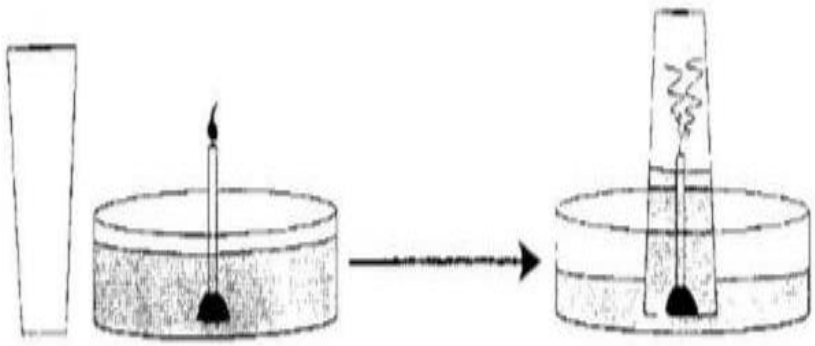

**Figure 6**. Hypothesis-deductive reasoning

The concept of the item in Figure 6 relates to several physics concepts: the combustion process of fire, the vacuum chamber, and the air pressure. Respondents who understand these concepts can immediately comprehend the pressure drop in the enclosed space resulting from combustion. The difference in air pressure between the space inside the glass and the atmospheric pressure pushes water into the glass. Respondents must first acknowledge that the initial hypothesis is incorrect and then design the necessary experimental evidence to support their conclusion. If respondents are unaware of the initial hypothesis's error, they will not produce proper hypothetical-deductive reasoning (Bhaw et al., 2023). In addition, respondents familiar with hypothesis testing activities will be able to reason about this process more quickly than respondents accustomed to passively receiving material or instruction from teachers.

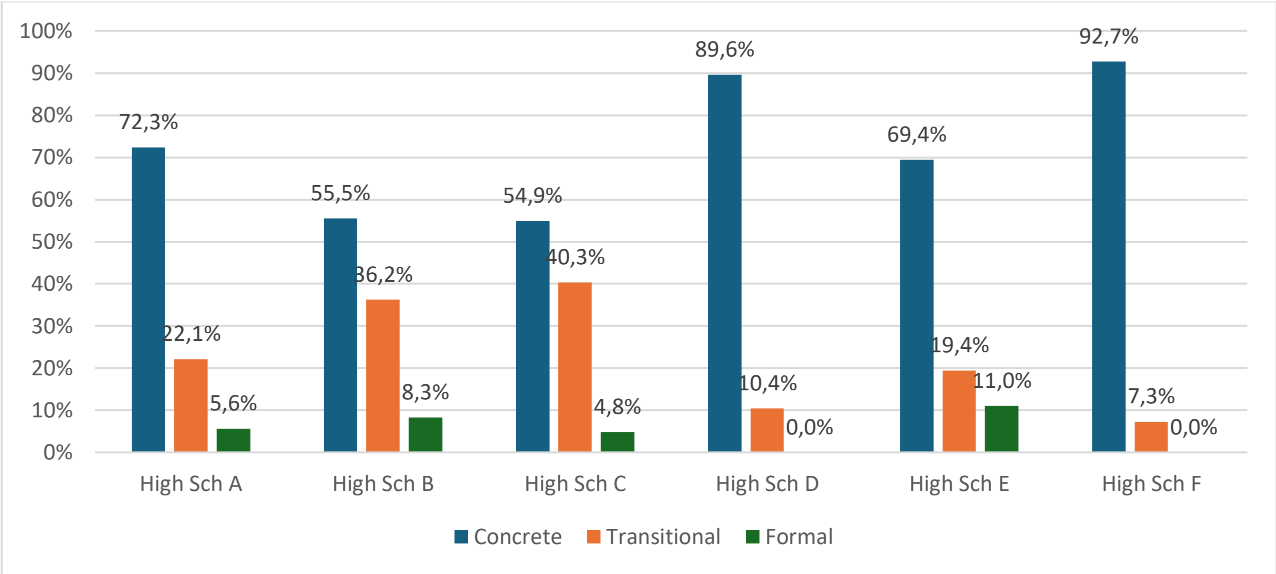


**Figure 7**. Students' scientific reasoning category

The total score of the scientific reasoning test answers can serve as a benchmark to categorize the abilities of each respondent. The categories of scientific reasoning, as outlined by the school, are shown in Figure 7 above. Three categories come from the phases of Piaget's cognitive development: concrete, transitional, and formal. The concrete category refers to the characteristics of the cognitive phase of concrete operations, where a child can think logically about concrete concepts, such as mathematics, science, and other concrete problems. Then, the formal category refers to the phase of formal operational development, where a child can think abstractly, understand abstract concepts, and use them to solve problems systematically. Finally, the transitional category refers to the cognitive development that occurs between concrete and formal operations (Han, 2013). In this category, a child still employs concrete thinking but has developed the ability to think abstractly in certain concepts.

Piaget's theory of cognitive development explains that a child at 12 years and above uses the formal operational phase. This means that High School students, whose average age is 16-17, should have been in this phase. However, the scientific reasoning test results show that many High School students in the city of Palangka Raya are operating at the concrete operational stage of thinking. Concrete ways of thinking will hinder respondents in making conversion reasoning, which involves creating a mental model to imagine the converted concept. Proportional reasoning also requires quantitative analysis of the relationship between two variables. Hypothetical-deductive reasoning requires a deep understanding of scientific inquiry procedures to produce mental experiments (Planinic et al., 2021). The entire scientific reasoning instrument requires thinking in the formal operational phase.

Several factors can potentially cause many students to remain at the concrete operational stage. The first factor is the influence of each student's environment and learning experience (Lawson, 2010). One of the main principles in Piaget's theory is that cognitive development is influenced by the interaction between students and their environment. If students' learning environment does not encourage abstract thinking and deep scientific analysis, they may not fully develop formal operational thinking skills. Learning in a classroom focusing on memorization or standard procedures without encouraging students to think critically can limit students' cognitive development.

The second factor potentially affecting students' thinking phase is the lack of exposure to scientific problems (Osborne, 2018). The ability to think formally is often associated with solving problems logically, thinking hypothetically, and processing abstract information. If students are rarely faced with scientific tasks that require critical reasoning or scientific problem-solving, they may struggle to develop these skills. Physics learning that focuses more on formulas and procedures without associating them with deep scientific reasoning can be an obstacle.

The third factor related to the low number of students who reach the formal operational phase is the quality of learning within the school itself (Bhaw et al., 2023). Data from each school also showed significant variation in the number of students in the concrete, transitional, and formal phases of learning. For example, High School D and F dominate the concrete stage, while High School A and E show more students in the transitional stage. This could indicate that the quality of teaching methods in these schools is less supportive of students developing abstract thinking skills. Teaching that is too teacher-centered without involving student exploration can slow cognitive development.

Physics educators can utilize several methods to facilitate the development of high school students' thinking to the formal operational stage. Teachers need to design physics learning that encourages abstract thinking and problem-solving activities. One effective strategy is the use of Problem-Based Learning (Wijnia et al., 2016). Through this learning model, students face real problems that require them to apply physics concepts logically and critically. By exploring problems independently and discussing them with their peers, students develop analytical thinking skills, formulate hypotheses, and draw conclusions based on scientific evidence. These activities help them build complex formal thinking skills.

Additionally, implementing open experiments in physics laboratories is crucial for facilitating cognitive development (Suma, 2010). Open-ended experiments differ from traditional experiments because students are not given detailed procedures. Instead, they are asked to design and conduct their investigations based on the questions or phenomena they face. In this process, students are expected to be able to identify variables, formulate hypotheses, control variables, and analyze results more independently. This experience can hone formal thinking skills because students must understand the relationships between physics concepts and apply them in a broader and abstract context.

Finally, teachers can also apply intensive group discussion methods to discuss abstract physics concepts (Hartsfield et al., 2021), such as the laws of thermodynamics or nuclear physics. Group discussions allow students to exchange ideas and see different problem-solving perspectives. Students in the concrete or transitional operational stage can benefit from listening to arguments from friends who can think abstractly. With the teacher's guidance, these discussions can help students organize their ideas, clarify their understanding, and test their conclusions using scientific reasoning.

## CONCLUSION

The results of the analysis of the scientific reasoning ability of High School students in Palangka Raya show that many students still use the concrete operational thinking stage. The scientific reasoning indicator that most respondents answered correctly was conservation reasoning. On the other hand, the weakest indicator is hypothetical-deductive reasoning. In the future, physics educators will need to design learning experiences that involve abstract thinking processes and problem-solving to help students develop the ability to think in a formal operational stage. Scientific reasoning can also be strengthened through learning experiences that incorporate open-ended experiments, allowing students to explore the process of scientific inquiry.

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