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Identification of Scientific Reasoning Ability of Junior High School Students

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ABSTRACT

Purpose – This study aims to 1) identify the level of scientific reasoning ability and 2) the difference between indicators of scientific reasoning ability of male and female junior high school students in Samarinda on climate change.

Methodology – The research method used is descriptive quantitative, with data collection techniques through tests in the form of multiple-choice questions with reasons totaling 11 questions that have been validated and tested for reliability. The subjects of this study were class VII students, totaling 86 students from 3 junior high schools in Samarinda. The instrument used was a scientific reasoning test consisting of 6 indicators: conservation reasoning, correlation reasoning, variable control, probabilistic reasoning, proportional reasoning, and deductive hypothesis.

Findings – The results showed that 1) The scientific reasoning ability of junior high school students in Samarinda averaged 45.63 in the transition stage between concrete and formal operations. Each indicator is in a different category: good, sufficient, and deficient. The highest result on the conservation reasoning indicator (65.33) shows that students adequately retain their knowledge, even though the appearance of the object changes. The lowest result on deductive hypothesis reasoning (35.08) shows that students cannot make conclusions on a problem. 2) There is no significant difference between male and female students in scientific reasoning ability related to climate change material in all junior high schools in Samarinda.

Contribution – This study provides recommendations for innovative learning methods, such as problem-based learning, to improve the scientific reasoning skills of male and female students.

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INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education aims to strengthen students' content knowledge and abilities, such as scientific reasoning (Jufri et al., 2016). (Hanson, 2016) Moreover, (Hadi et al., 2021) state that scientific reasoning is applying logical and systematic principles to the scientific

method, including finding problems, formulating hypotheses, making predictions, creating experiments, controlling variables, and analyzing data. The core component of scientific reasoning is the ability to design controlled experiments and evaluate the evidence produced about one's hypothesis (Malik, 2021). Students with good scientific reasoning skills are expected to construct concepts better and make decisions for problem-solving activities.

Scientific reasoning is critical to train because it is the foundation of the discovery process and the basis for developing other skills, such as critical thinking (higher-order thinking) and problem-solving (Nugraha et al., 2017). These thinking skills can affect students' academic performance in classroom learning, everyday decision-making, and student success. Therefore, scientific reasoning needs to be practiced in science learning, and factors that influence scientific reasoning include the learning process, habits, age, and learning experience (Balqis et al., 2019).

Measuring students' scientific reasoning ability is essential because it allows educators and researchers to understand how well students can apply scientific thinking to real-world problems and understand scientific information (Palian et al., 2025). Measuring scientific reasoning ability can help students develop the critical thinking and problem-solving skills necessary for success in science and other areas of life (Bhaw et al., 2023). This understanding can improve science education by identifying areas where students struggle and developing strategies to support their learning. In addition, measuring scientific reasoning ability can also help assess the effectiveness of various teaching methods and curriculum materials.

(OECD, 2023) stated that the average PISA results in 2022 decreased compared to 2018 in math, reading, and science. Overall, the results in 2022 were among the lowest ever measured by PISA in all three subjects, on par with the results obtained in 2003 in reading and math and 2006 in science. Although the results of the previous few assessments were higher than those observed in the early years, this improvement was reversed by the decline seen from 2015 onwards. Indonesia's low PISA results, especially in the science aspect, can also indicate the weak scientific reasoning of students in Indonesia.

Science learning is closely related to various natural phenomena in everyday life, such as climate change issues. Climate change is one of the world's main problems today, and its handling is a focus in various aspects of life and is included in the Sustainable Development Goals (Demaidi & Al-Sahili, 2021; Efwinda et al., 2023; Hakim et al., 2023). Scientific reasoning skills on problems related to climate change need to be applied in thinking logically and systematically, making hypotheses to test, and making decisions to solve problems. Students' problems in scientific reasoning, especially in junior high school science learning, often relate to a lack of in-depth understanding of basic scientific concepts. Many students have difficulty connecting theory with real practice, so they memorize information without understanding it. In addition, the lack of skills in formulating hypotheses and designing appropriate experiments is also a significant obstacle. Students are often unfamiliar with systematic scientific methods, such as controlling variables and interpreting experimental data (Ridwan et al., 2024).

Research on students' scientific reasoning skills has shown an increased commitment of science education stakeholders to focus on building and developing students' scientific reasoning skills. Research conducted by Firdausi et al. (2020) in the Senior High School category examined students' scientific reasoning skills on elasticity and Hooke's law. Research conducted by Rimadani and Diantoro (2017) in the Senior High School category examined students' scientific reasoning on temperature and heat topics. It showed that students' scientific reasoning results were still relatively low. Research conducted by Anjani et al. (2020) in the Senior High School category examined that the guided inquiry learning model, accompanied by multidimensional thinking diagrams, can improve students' scientific reasoning abilities, especially in the proportional and conservation reasoning domains. Research conducted by Sundari & Rimadani (2020) in the Senior High School category examined that the application of guided inquiry learning with scaffolding strategies can improve the scientific reasoning abilities of students in class X MIA 1 SMA Negeri 1 Krian Sidoarjo on temperature and heat material.

A study conducted by Hadi et al. (2021) in the Junior High School category found that female and male

students have different scientific reasoning abilities on specific indicators. Character, other brain structures, and student environments cause differences in scientific reasoning abilities. Another study by Nabillah et al. (2022) showed that gender does not affect a person's scientific reasoning ability. The average score shows the level of scientific reasoning of male and female students at the same percentage. However, from the existing studies on scientific reasoning, no research identifies the Scientific Reasoning Ability of Junior High School Students in Samarinda on the Climate Change Topic. Differences in student scientific reasoning based on gender also still show mixed results. Based on direct observation, some Samarinda students cannot still analyze facts or information logically and systematically. A lack of interest in reading and searching for information makes it difficult for students to solve problems. Scientific reasoning skills are essential for students because they can improve their understanding of scientific concepts and develop a deep understanding. Scientific reasoning skills are also needed to face global challenges like climate change and technological developments. Therefore, this study aims to 1) identify the level of scientific reasoning ability and 2) identify differences in indicators of scientific reasoning ability of male and female junior high school students in Samarinda on climate change. This research is essential to determine the extent of the scientific reasoning abilities of junior high school students in Samarinda. This study can develop scientific thinking processes in students, improve scientific thinking skills in climate change material, and develop effective strategies to improve students' scientific reasoning skills. This study uses multiple-choice questions with explanations of climate change material. The questions used have been tested for validity and reliability beforehand.

METHODOLOGY

Research Design

This research is a descriptive study with a quantitative approach to identify the scientific reasoning ability of junior high school students on Climate Change topics. Descriptive research does not aim to test specific hypotheses but only to describe what is associated with a variable. In contrast, quantitative research requires using numbers, starting from data collection, interpretation, and presentation of results.

Participants

To measure students' scientific reasoning ability, the research was conducted at three junior high schools in Samarinda city, namely SMPN A Samarinda, SMPN B Samarinda, and SMPN C Samarinda. Samples were taken at SMPN A Samarinda with a total of 28 students, SMPN B Samarinda with a total of 23 students, and SMPN C Samarinda with a total of 35 students for a total sample of 86 students. Details of the number of students can be seen in Table 1.

Table 1. Details of the Number of Students

School Name	Number of Male Students	Number of Female Students
SMPN A Samarinda	13	15
SMPN B Samarinda	11	12
SMPN C Samarinda	20	15
Total	44	42

Data Collection

The technique used to determine the sample in this study is cluster random sampling, which is used when the population does not consist of individuals but groups of individuals or clusters. The data collection technique used in this study is a test instrument about scientific reasoning ability by analyzing each item. Then, the data is collected through direct observation. The instrument to determine students' scientific reasoning ability is 11 multiple-choice questions with climate change material. Students' scientific

reasoning ability is measured using Lawson's Classroom Test of Scientific Reasoning (LCTSR), which consists of conservation reasoning, proportional reasoning, variable control, probability reasoning, correlation reasoning, and hypothesis-deductive reasoning (Cahyaningrum, 2019; Hrouzková & Richterek, 2021; Lawson, 1978).

Instrument

The instrument used in this study is a question instrument used to measure the scientific reasoning ability of junior high school students regarding Climate Change. The instruments used during the implementation of the survey were instruments that had been validated by experts and had been tested for validity and reliability. The instrument consisted of 11 questions on scientific reasoning ability regarding climate change, following six indicators of Lawson's Classroom Test of Scientific Reasoning (LCTSR): conservation reasoning, proportional reasoning, variable control, probability reasoning, correlation reasoning, and hypothesis-deductive reasoning.

The validity test began with 20 multiple-choice questions developed with clear reasons. Four expert lecturers became validators to provide an assessment of the question instrument developed. The results of this test show that all questions can be used, although some require improvement. Since no questions were discarded at this stage, the empirical validity test was conducted. At this stage, the results showed that out of 20 questions, 15 were declared valid, while five questions were invalid and had to be corrected, as seen in Table 2.

Table 2. Validity Test Results Using SPSS

Question Number	r-Count	r-Table	P (Sig.)	Description
Conservation 1	-0,018	0,339	0,918	Invalid
Conservation 2	0,258	0,339	0,141	Invalid
Conservation 3	0,462	0,339	0,006	Valid
Correlation 4	0,484	0,339	0,004	Valid
Correlation 5	0,202	0,339	0,252	Invalid
Correlation 6	0,474	0,339	0,005	Valid
Correlation 7	0,369	0,339	0,032	Valid
Correlation 8	0,487	0,339	0,004	Valid
Variable Control 9	0,419	0,339	0,014	Valid
Variable Control 10	0,608	0,339	0,000	Valid
Variable Control 11	0,473	0,339	0,005	Valid
Probabilistic 12	0,547	0,339	0,001	Valid
Probabilistic 13	0,455	0,339	0,007	Valid
Probabilistic 14	0,712	0,339	0,000	Valid
Proportional 15	0,382	0,339	0,026	Valid
Proportional 16	0,515	0,339	0,002	Valid
Proportional 17	0,110	0,339	0,535	Invalid
Deductive Hypothesis 18	0,479	0,339	0,004	Valid
Deductive Hypothesis 19	0,296	0,339	0,089	Invalid
Deductive Hypothesis 20	0,398	0,339	0,020	Valid

In this study, questions declared valid are selected based on each indicator, with two questions taken for each correlation indicator, variable controller, probabilistic, proportional, and deductive hypothesis, and 1 question for the conservation indicator. After this process, the total number of previously 15 questions became 11. The number of questions was reduced to ensure that the remaining questions represented the indicators measured and were of high quality.

After the validity test is carried out, a reliability test is carried out to obtain a valid and reliable instrument. The reliability test was carried out at SMPN D Samarinda, class VII, with 34 students. The

number of questions tested was 20 multiple-choice questions. The reliability test was conducted using IBM SPSS Statistics 25 using Cronbach's Alpha formula. The results of the reliability test data show that the Alpha obtained is 0.657, which means that the Alpha value lies in 0.50-0.70, indicating moderate reliability. The research sample used to measure scientific reasoning ability was all students of class VII-D of SMP Negeri A Samarinda, totaling 28 students; all students of class VII-A of SMP Negeri B Samarinda, totaling 23 students; and all students of class VII-A of SMP Negeri C Samarinda, totaling 35 students.

Data Analysis

To identify the scientific reasoning skills possessed by students in climate change material, a scientific reasoning ability test instrument is needed in this study, using 11 items of reasoned choice questions. (Handayani et al., 2020) Stated that at the scoring stage, each item is given a score of 1 if the content question and the reasoning question are correct; if one of the content questions and the reasoning question is wrong, then it is given a score of 0, and likewise, if both answers are bad it is given a score of 0. The scientific reasoning categories can be seen in Table 3.

Table 3. Scientific Reasoning Categories

Score (%)	Category
81 ≤ 100	Very Good
61 ≤ 80	Good
41 ≤ 60	Simply
≤ 40	Less

Source: (Handayani et al., 2020)

Then, analyze the achievement of each scientific reasoning indicator by calculating the overall percentage of scientific reasoning ability using the formula proposed by (Handayani et al., 2020) as follows:

$$P = \frac{f}{n} \times 100\% \quad (1)$$

P = percentage of answers
f = Frequency of student answers
n = number of students

There are three levels of scientific reasoning ability, namely the concrete operational level, the transitional level, and the formal operational level. A significant difference can be observed by comparing the concrete and formal operational levels, as, according to Piaget's theory, children's scientific reasoning ability can be classified into four stages. The sensorimotor stage is found in children aged 0-2 years, the pre-operational stage in children aged 2-7 years, the concrete operational stage in children aged 7-11 years, and the formal operational stage in children aged 11 years and above. According to these developmental stages, the research will evaluate the extent of the scientific reasoning ability of students over 11 years old (Wilujeng et al., 2021). The level of scientific reasoning ability can be seen in Table 4.

Table 4. Level of Scientific Reasoning Ability

Level of scientific reasoning ability	Value
Good (Formal)	71-100
Simply (Transitional)	36-70
Less (Concrete)	0-35

Sumber: (Piaget, 2019)

A normality test was first conducted to determine the difference in scientific reasoning ability between male and female students. The purpose of the normality test is to determine whether the data distribution is normally distributed, using IBM SPSS Statistics 25 with the Kolmogorov-Smirnov test technique. After obtaining normal data, a homogeneity test is carried out, which is used to determine whether the variants of

the data distribution are the same or not. If the same is called homogeneous, and the data is not the same, it is called inhomogeneous. The homogeneity test uses IBM SPSS Statistics 25 with the Levene test technique. The t-statistical test is a tool to show how far the influence of one independent variable is in explaining the dependent variable. The t-statistical test or t-test uses a significance level 0.05 (α = 5%).

FINDINGS

Scientific Reasoning Ability

The assessment of student's scientific reasoning abilities aims to determine the category of students' abilities after being given scientific reasoning question instruments related to climate change topics.

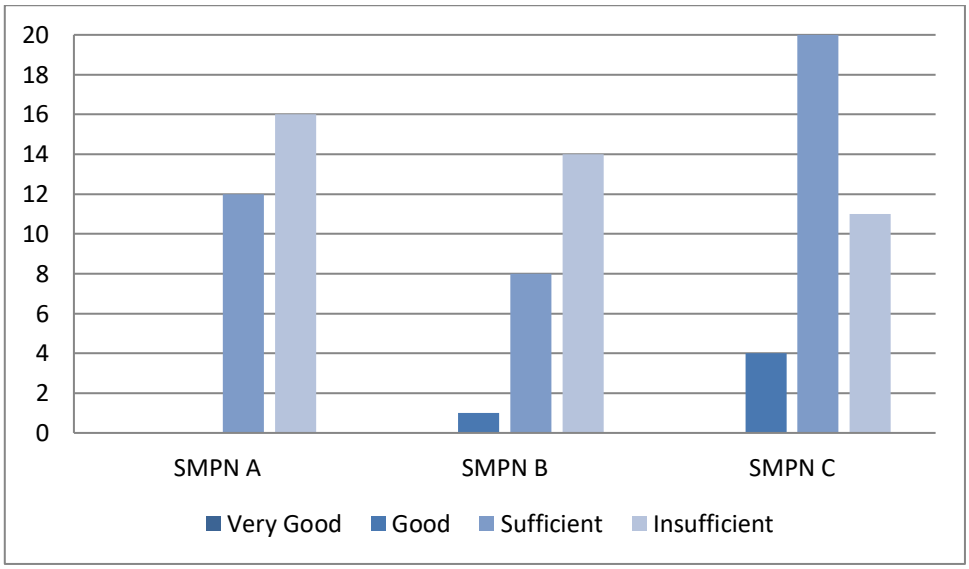

Figure 1. Scientific Reasoning Ability Category

Figure 1 shows the scores of seventh-grade students. In the results at SMP Negeri A, 16 students were found insufficient, and 12 were in the sufficient category. At SMP Negeri B, there are 14 students in the inadequate category, 8 in the adequate category, and 1 in the good category. Furthermore, in SMP Negeri C, there are 11 students in the insufficient category, 20 in the sufficient category, and 4 in the good category. Data on the percentage of scientific reasoning results can be seen in Table 5.

Table 5. Percentage data of scientific reasoning results

School Name	Very Good (81 ≤ 100%)	Good (61 ≤ 80%)	Sufficient (41 ≤ 60%)	Insufficient (≤ 40%)	Percentage
SMPN A Samarinda	0	0	12	16	40,94
SMPN B Samarinda	0	1	8	14	42,54
SMPN C Samarinda	0	4	20	11	47,86

The assessment of student's scientific reasoning ability also aims to determine the improvement of scientific reasoning based on six indicators: conservation reasoning, correlation reasoning, variable control, probabilistic reasoning, proportional reasoning, and hypothesis-deductive reasoning. Per-indicator scientific reasoning ability can be seen in Figure 2.

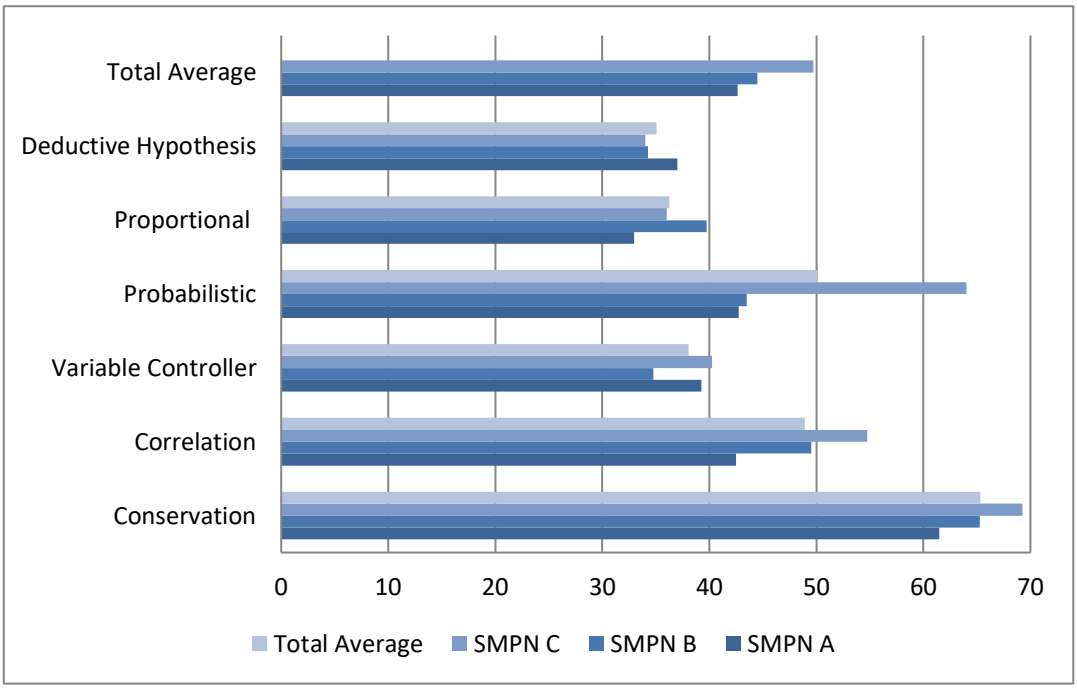

Figure 2. Scientific Reasoning Ability Per-Indicator

Based on Figure 2, it can be seen that the average acquisition of each scientific reasoning indicator at junior high schools in Samarinda is in a different category, namely the good, sufficient, and deficient categories. As for the level of each indicator, the average is at the transition stage. At SMP Negeri A, the conservation reasoning indicator obtained an average of 61.5, the correlation reasoning indicator obtained an average of 42.5, the variable controller obtained an average of 39.25, probabilistic reasoning obtained an average of 42.75, proportional reasoning obtained an average of 33, and the deductive hypothesis reasoning indicator obtained an average of 37.

Table 6. Percentage data of scientific reasoning results per indicator

Indicator	Question Nuber	Average Assessment			Average/ Indicator	Category	Level
		SMPN A	SMPN B	SMPN C			
Conservation	1	61,5	65,25	69,25	65,33	Good	Sufficient
Correlation	2-3	42,5	49,5	54,75	48,92	Sufficient	Sufficient
Variable Controller	4-5	39,25	34,75	40,25	38,08	Insufficient	Sufficient
Probabilistic	6-7	42,75	43,5	64	50,08	Sufficient	Sufficient
Proportional	8-9	33	39,75	36	36,25	Insufficient	Sufficient
Deductive Hypothesis	10-11	37	34,25	34	35,08	Insufficient	Insufficient
Total average of the indicator					45,63		
Average Per-School		49,71	42,67	44,5	45,63		

Furthermore, at SMP Negeri B, the conservation reasoning indicator obtained an average of 65.25, the correlation reasoning indicator obtained an average of 49.5, the variable controller obtained an average of 34.75, and probabilistic reasoning obtained an average of 43.5. Proportional reasoning obtained an average of 39.75. The deductive hypothesis reasoning indicator obtained an average of 34.25. At SMP Negeri C, the conservation reasoning indicator obtained an average of 69.25, the correlation reasoning indicator obtained an average of 54.75, the variable controller obtained an average of 40.25, probabilistic reasoning obtained an average of 64, proportional reasoning obtained an average of 36, and deductive hypothesis reasoning indicators obtained an average of 34. The total average of all indicators at SMP Negeri A was 42.67; at SMP

Negeri B, the total average was 44.5; and at SMP Negeri C, it amounted to 49.71. The total average of all schools is 45.63. Percentage data from the results of scientific reasoning per indicator can be seen in Table 6.

Differences in Scientific Reasoning Ability of Male Students and Female Students

Based on the study's results, data from all schools showed that the distribution was normal and homogeneous. After the data were found to be regular and homogeneous, the Independent Sample Test was conducted to see the difference in scientific reasoning ability between male and female students. The study data from all schools showed a significant value > 0.05, so it can be concluded that H_0 is accepted and H_1 is rejected. This means that there is no significant difference between males and females in scientific reasoning ability related to climate change material. The values for normality, homogeneity, and independent sample tests can be seen in Table 7.

Table 7. Values for normality, homogeneity, and independent sample tests

School Name	Normality Test	Test Homogeneity	Independent Sample Test
SMPN A Samarinda	0,194 (Normal)	0,982 (Homogen)	0,469 (Significant)
SMPN B Samarinda	0,246 (Normal)	0,633 (Homogen)	0,559 (Significant)
SMPN C Samarinda	0,162 (Normal)	0,558 (Homogen)	0,644 (Significant)

DISCUSSION

The average student's scientific reasoning skills score is sufficient based on the study's results. They were in the moderate category or the transition stage from concrete operations to formal operations. This means that junior high school students (as participants in this research) at this age begin to move from the concrete thinking stage to abstract thinking but are still in a transitional process. According to Piaget's theory, children's scientific reasoning ability can be classified into four stages. The sensorimotor stage is found in children aged 0-2 years, the pre-operational stage in children aged 2-7 years, the concrete operational stage in children aged 7-11 years, and the formal operational stage in children aged 11 years and over (Wilujeng et al., 2021).

The scientific reasoning test produced scores ranging from 34 to 70. These scores are obtained from test results formulated based on scientific reasoning categories. At this transitional stage, students begin to show the ability to think abstractly, but only in a limited context. They tend to be able to answer questions correctly, but the explanations are still brief and do not fully reflect the scientific reasoning indicators they should be. The picture of this research can be a basis for consideration of how teachers design learning strategies that can bridge the abilities of students who are mostly still in the transition category, for example, by using contextual learning strategies or using certain learning media that can help visualize the abstract concepts that students are learning, especially related to the topic of climate change.

In addition, the results also show that students are still unable to use their knowledge to carry out scientific reasoning activities, such as conducting simple experiments, explaining data taken from data sets, making conclusions, using abstract scientific principles to explain new things, and formulating hypotheses based on theory and scientific evidence. Therefore, students also need to be accustomed to learning with the scientific method so that they are used to identifying problems, formulating and testing hypotheses, controlling variables, analyzing data, and determining problem solutions. Students' low scientific reasoning ability can impact Indonesian education, where Indonesia's educational achievement is in the low category compared to other countries. Meanwhile, the impact on students is that they will find it challenging to solve science problems. Based on this fact, it is essential to implement a learning model that requires students to play an active role widely in learning (Wulandari et al., 2024).

The ability tested in this study is the student's ability to answer questions that include six scientific reasoning indicators Lawson developed: conservation reasoning, correlation reasoning, variable control, probabilistic reasoning, proportional reasoning, and hypothesis-deductive reasoning. Each indicator improvement has different categories: good, sufficient, and deficient. In the conservation reasoning indicator, students obtained an average of 65.33, while in the correlation reasoning indicator, the average was 48.92. The variable control indicator averages 38.08, the probabilistic reasoning indicator is 50.08, proportional reasoning is 36.25, and hypothesis-deductive reasoning is 35.08. This condition shows that some students are starting to be able to use scientific reasoning; however, their abilities are not evenly distributed across all indicators measured. Therefore, a science learning environment is needed that can facilitate students to practice developing their scientific reasoning, especially on the deductive hypothesis reasoning indicator, because this indicator has the lowest score.

The indicator that obtained the highest average was conservation reasoning, with an average value of 65.33. This shows that most students can maintain their knowledge, even though the object's appearance changes, because they understand that its basic properties remain the same. Meanwhile, the indicator that obtained the lowest score was deductive hypothesis reasoning, with an average value of 35.08. Deductive hypothesis reasoning is students' ability to conclude (Utami et al., 2020). This is in line with the research of (Firdaus et al., 2021), which states that junior high school students cannot yet compare two variables of a phenomenon based on a constant ratio, which means that junior high school students have low scientific reasoning skills on the deductive hypothesis indicator.

Based on the study's results, data from all schools showed that they were normally distributed and homogeneous, and there was no significant difference between the scientific reasoning ability of male and female students. This result contradicts the statement by Hadi et al. (2021) that female and male students have different scientific reasoning abilities on specific indicators. Brain structure plays a role in shaping scientific reasoning ability. In general, brain size is different between men and women. Men have a larger brain size than women. In the development process, men's and women's brains do not follow the same pattern. Generally, men develop the right brain first and then the left brain. However, in women, brain development is more balanced between the left and right brain (Amin, 2018).

This research result follows the statement of Nabillah et al. (2022), which states that gender does not affect scientific reasoning ability. However, teaching methods and learning experiences are also very influential. In schools with supportive educational facilities or more interactive teaching methods, students' scientific reasoning skills can develop more evenly, regardless of gender differences. Other characters, brain structures, and student environments affect each individual's scientific reasoning abilities. The absence of a difference in scientific reasoning based on gender can be caused by several factors, such as schools that are aligned in providing learning opportunities to all students regardless of gender.

In general, internal factors such as brain structure may play a role in shaping scientific reasoning ability. Still, external factors such as learning environment, teaching methods, and learning experiences are also very influential. In addition, among male students, social interactions more often focus on competition and individual work, which correlates with their tendency to excel in spatial and logical reasoning (Manurung & Panggabean, 2018; Mehta et al., 2024). In contrast, social interactions among female students tend to be more collaborative and communicative (Hajibabaei et al., 2023; Love et al., 2022), which allows them to capitalize on strengths in verbal memory and discussion-based understanding. These factors may influence how male and female students understand and apply scientific reasoning skills to climate change topics. In addition, teachers should use learning methods that support active participation from all male and female students so that the development of scientific reasoning skills does not depend too much on gender differences. In schools with better educational facilities or more interactive teaching methods, students' scientific reasoning skills may develop more evenly, regardless of gender differences.

The results of this study can be used to develop theories of climate change and the importance of scientific reasoning in learning. Scientific reasoning in learning is important because it can help students

understand scientific concepts, develop problem-solving skills, and improve scientific literacy. This study's sample size was small, and many students did not provide reasons for their answers, resulting in low scores.

CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the scientific reasoning ability of junior high school students in Samarinda is at the transition stage from concrete operations to formal operations. Each indicator is in a different category: good, sufficient, and deficient. The highest result in the conservation reasoning indicator, with an average value of 65.33, shows that students can maintain their knowledge even though the appearance of the object changes. The lowest result on deductive hypothesis reasoning, with an average score of 35.08, shows that students have not been able to come to conclusions about a problem. The average result of students from all schools was 45.63. There is no significant difference between male and female students in scientific reasoning ability related to climate change material in all junior high schools in Samarinda.

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