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Exploration of Scientific Reasoning Skills Students' on Material Growth and Development of Plants Class XII MIPA Based Gender at SMAN Ambulu Jember

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Abstract. Education is an important element for a person's life in any country. Indonesia has taken the Program for International Student Assessment (PISA) test since 2001. Since then, Indonesia's scores in science have fluctuated but have remained flat. So, scientific reasoning skills are needed that can help students understand science, especially in biology. Moreover, scientific reasoning skills are standard substance for graduates as stated in Minister of Education and Culture Regulation Number 21 of 2016. The purpose of research is to describe the scientific reasoning skills of male and female students on material plant growth and development class XII MIPA 3 at SMAN Ambulu Jember. The research method used is a qualitative for case study type. The research location chosen was SMAN Ambulu Jember. The subjects were selected using purposive sampling technique. The data collection techniques are tests, interviews, observation and documentation. The data analysis technique used of Miles and Huberman Model qualitative data analysis which consists of 4 stages are data collection, data condensation, data display and conclusion drawing/verification. Based on the results, scientific reasoning skills of male and female students are good category. From the test results, there are 7 male students belonging to transitional operational patterns, while there are 5 male students belonging to formal operational patterns. The female students belonging to the formal operational patterns are 18 people and 6 female students with the transitional operational patterns. In conclusion, this study sheds light on the commendable scientific reasoning skills demonstrated by both male and female students in understanding material on plant growth and development in class XII MIPA 3 at SMAN Ambulu Jember.

Keywords: Biology learning, Education, Gender, Scientific reasoning skills

INTRODUCTION

In essence, every human being needs education in everyday life. According to Government Regulation Number 57 of 2021 Chapter 1 Article 1, education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble morals, and skills needed by oneself, society, nation and state. Education is a component that is given great attention in Indonesia, because education is a supporting factor for a country's progress. Quality education can form a good generation and can bring change in the future (Lestari et al., 2023).

Indonesia has taken the Program for International Student Assessment (PISA) test since 2001. Since then, Indonesia's scores in science have fluctuated but overall have remained flat. From data from the Organization for Economic Co-Operation and Development (OECD), Indonesia's results on the PISA science skills test tend to decline every year. In 2006 the science score of Indonesian students reached 393, but in 2009 the science score dropped drastically by 10 points, bringing the score to 383. In the following year the science score of Indonesian students also decreased to 382. In 2015 the results of the Program for International Student Assessment test (PISA), Indonesia's science ability increased to a score of 403. However, in 2018 Indonesia's Program for International Student Assessment (PISA) science test score decreased from the previous year to 396 (PISA, 2018).

Indonesian students have studied science since they were at elementary school level, which is usually called science subjects. At the high school level, science lessons are divided into 3 lessons, one of which is biology. Biology subjects contain abstract and complex material and involve certain and interconnected bioprocesses (Aini, 2022). This fairly broad coverage of material requires students to have higher thinking skills as the basis for their knowledge. To train these abilities, students need to be trained in scientific reasoning skills. Scientific reasoning skills are an ability that is closely related to various problems and investigations which are also related to the use of scientific methods. Scientific reasoning skills can be seen and assessed through scientific reasoning indicators and scientific reasoning patterns (Jariah, 2022). Scientific reasoning consists of thinking abilities that involve processes of inquiry, evaluation, inference, argumentation, and experimentation. Scientific reasoning is the overall pattern of reasoning, which includes deductive hypotheses and sub-patterns which include formal operational schemes such as proportions and combinatorial correlations (Piraksa, 2014).

The presence of scientific reasoning skills allows students to handle new situations and design investigations and solve scientific and social problems in the real world. In line with Ayu Syifa Fauziah's research, she explained that good scientific reasoning skills are an aspect that is really needed in science and everyday life as well as capital to compete in the 21st century. Learning in schools needs to know the extent of students' scientific reasoning skills in order to further optimize and train them.

students' scientific reasoning skills (Fauziah, 2020). Reasoning skills are also required by students as the substance of Graduate Competency Standards to achieve national education goals contained in Minister of Education and Culture Regulation Number 21 of 2016 concerning Primary and Secondary Education Content Standards which include reasoning, processing and presenting skills.

Based on the results of a preliminary study in the form of an interview on May 25 2023 with Mrs. Amaliyah Farida as a biology teacher for class However, based on learning outcomes in the form of assignments and daily test scores as well as students' activeness in the learning process, students' scientific reasoning skills vary greatly, some are high, fair and low. In terms of gender, the majority of female students have a better way of thinking than male students. This situation is caused because female students tend to be active during learning.

Supported by observations during the learning process, female students are more active than male students. Male students prefer to be quiet when studying. However, when outside of learning activities, they actively mingle with their friends. This situation is in accordance with the statement made by Amin (2018) that the anatomical structure of the brain between men and women is different, in terms of size, volume and thickness. In terms of how the brain is used, male students tend to use the left brain, while female students often use the right brain. Therefore, female students can outperform male students. In addition, men's brains are larger than women's brains. Likewise, differences in the brain structure of men and women were found in the corpus calossum, hypothalamus, lower parietal lobe and hippocampus. These differences in anatomy and size can have implications for the way different individuals think.

From the results of interviews with class XII MIPA 3 students, the material that students considered difficult was the material on growth and development in plants. This material is part of biological material which has a developing and tiered concept from simple to complex and interrelated concepts. According to students, this material is material that is considered difficult because there are many new terms in plant growth and development, the names of hormones and the very complex bioprocess of plant development. And student learning resources are still focused on textbooks and LKS books. This statement is in line with Widiastuti's (2020) research from the results of the questionnaire analysis distributed to students, the material that was considered difficult to understand was the material on plant growth and development, specifically the sub-material of plant hormones. In research by Putri et al. (2022) also explained that plant material is material that is difficult for students to understand with the percentage of students answering quite difficult being 42.4%, neutral 19.2%, and quite easy 38.4%. Therefore, there is a need for research to measure students' level of scientific reasoning which can later also be used to evaluate students' learning success, especially in the material on plant growth and development.

During learning, students have different abilities when receiving, analyzing information, and solving biological problems. Differences between students when receiving information and solving problems can be influenced by many factors, one of which is gender differences. Gender according to biological theory is the development of sex which includes hormonal activity and individual behavior. Several studies show that men have high testosterone levels. Apart from hormonal influences, brain use will also influence thinking patterns. Male students tend to use their left brain so they have the ability to think abstractly, logically and analytically, while female students tend to use their right brain, as a result they will be active linguistically, imaginatively, holistically, perceptively and with some visual abilities (Lestari, 2016). Gender is regarded as one of the foremost and commonly cited background attributes (Nasution et al., 2023).

In Anjani et al. (2022) research, the results of physics students' scientific reasoning tests showed that female students scored higher than male students and that female students scored the highest on the indicators of correlational reasoning and hypothetical-deductive reasoning. In line with research by Hadi et al. (2021), the research results obtained show that female and male students have different scientific reasoning abilities in science learning on certain indicators. The indicators used in this research are correlation reasoning, probabilistic reasoning and proportional reasoning. Of these three indicators, female students got superior scores than male students, namely the correlation reasoning and probabilistic reasoning indicators, while male students got high scores on the proportional reasoning indicator. He also explained that female students often write and solve problems through writing and discussion, which is consistent with correlational and probabilistic reasoning.

From this description, it is necessary to conduct research on students' scientific reasoning in gender-based biology material. Because no one has yet conducted research on the level of gender-based scientific reasoning, especially regarding growth and development in plants. Therefore, researchers are interested in conducting research regarding the exploration of students' scientific reasoning skills in gender-based biology material.

METHOD

This research used a qualitative approach, so that researchers can explore in depth the phenomena observed, so that later they can be interpreted in life (Sugiyono, 2022). The type of research used is case study on scientific reasoning skills on material plant growth and development class XII MIPA 3 based gender at SMAN Ambulu Jember. The research location chosen was SMAN Ambulu Jember. The researcher chose this location, because SMAN Ambulu Jember is one of the leading A accredited State High Schools and is one of the favorite schools in South Jember area. Determining

research subjects used purposive sampling technique. The research subjects used were class XII MIPA students and biology teachers.

Data collection techniques are tests, interviews, observation and documentation. The scientific reasoning test takes the form of 12 essay questions. The preparation of this test is adjusted for indicators of scientific reasoning skills are conservation reasoning, proportional reasoning, variable control reasoning, probabilistic reasoning, correlation reasoning and hypothesis-deductive reasoning. The test results obtained were then calculated for the percentage for each indicator of scientific reasoning skills. The percentage of scientific reasoning skills is calculated using the formula :

$$P = \frac{total\ score\ obtained}{maximum\ score} \times 100\%$$

Then proceed with categorizing the level of students' scientific reasoning skills based on indicators. The categories of students' scientific reasoning skills can be seen in the Table 1.

Table 1. Category level of scientific reasoning.

Score	Category
0 – 20	Very less
21 – 40	Less
41 – 60	Enough
61 – 80	Good
81 – 100	Very good

Source: Jariah (2022).

The categories of students' scientific reasoning patterns can be seen in the Table 2.

Table 2. Category level of scientific reasoning patterns.

Score	Levels of Scientific Reasoning Patterns
0 – 35	Concret operational
36 – 70	Transitional operational
71 – 100	Formal operational

Source: Jariah (2022).

The form of interview used is a semistructured interview. Observation techniques provide data of teacher and student activities during the biology learning process in the classroom and outside it. Documentation in this research are a list student names of class XII MIPA, a recapitulation of the grades of class and photos of learning activities. The data analysis technique used is the Miles and Huberman Model qualitative data analysis which consists of 4 stages are data collection, data condensation, data display and conclusion drawing/verification. The validity of the data used is technical triangulation and source triangulation.

FINDINGS AND DISCUSSION

Scientific reasoning skills are a rational thinking ability where skills are formed based on certain indicators. There are 6 indicators used in this research, namely indicators of conservation reasoning, proportional reasoning, variable control reasoning, probability reasoning, correlation reasoning and hypothetical-deductive reasoning. Table 3 is the percentage indicators of male students' scientific reasoning skills.

Table 3. Scientific reasoning skills of male students.

Number	Indicator of Scientific Reasoning	Percentage	Category
1	Conservation Reasoning	84%	Very good
2	Proportional Reasoning	75%	Good
3	Variable Control Reasoning	60%	Enough
4	Probabilistic Reasoning	66%	Good
5	Correlation Reasoning	58%	Enough
6	Hypothesis-Deductive Reasoning	74%	Good

The scientific reasoning skills of male students are in the good category. On the conservation reasoning indicator, male students obtained a percentage of 84%. This proves that students are able to understand the questions very well, so that students get very high scores on this indicator. In line with the statement of Azmi, Astutik & Subiki (2020), students can be categorized as having excellent conservation reasoning abilities, if they can maintain their knowledge, even though the appearance of the object changes, the nature of an object remains the same. The percentage of scores obtained by male students on the proportional indicator is 75%. This is proven by the description of students' correct answers and linking them to the theories they have studied. Psychologically, proportional reasoning is a way of thinking that involves sensitivity regarding quantitative relationships and ratio comparisons. According to Walle, proportional reasoning abilities are used to describe the thoughts and concepts needed to understand speed, ratio and proportion, including scale. The impact of low proportional reasoning abilities can make it difficult for students to make conclusions, this will certainly hinder students in the learning process (Nagara, Musyaffa & Kusairi, 2018). Psychologically, proportional reasoning is a way of thinking that involves sensitivity regarding quantitative relationships and ratio comparisons. According to Walle, proportional reasoning abilities are used to describe the thoughts and concepts needed to understand speed, ratio and proportion, including scale. The impact of low proportional reasoning abilities can make it difficult for students to make conclusions, this will certainly hinder students in the learning process.

The percentage of student scores obtained on the variable control indicators is 60% in the sufficient category. Similar to the research of Handayani, Windyariani & Pauzi (2020), the variable control reasoning indicator received a percentage of 41.1% which was included in the sufficient category. Furthermore, Yunita Ainun Jariah (2022) research results explain that many students are still confused by the variables presented, as a result, many students answer questions on variable control reasoning

indicators with incorrect answers. The percentage of probability reasoning scores obtained by male students was 66% in the good category. The results of this research are in line with the findings of Sundari and Rimadani (2019) where students have not been able to analyze information well based on data. This error occurs because when solving probability problems, students often utilize strategies based on previous experience, beliefs, and intuitive strategies (Sharma, 2006).

The majority of male students answered incorrectly on questions with correlation reasoning indicators. The score obtained on this indicator was 58% in the sufficient category. The score obtained was due to students answering questions that were related, but could not determine the keywords needed and could not even understand them (Fauziah, 2020). The low scores obtained by students in correlation reasoning indicate that students are still weak in correlating the causes and effects of events (Sundari & Rimadani, 2019). The percentage of male students' scores on this indicator was 74% in the good category. From the results of the interviews, students also said that they had to read the questions repeatedly to understand the questions presented. This statement is similar to the research results of Andani, Prastowo, & Supeno (2018), in which several students were found to be able to answer hypothetical-deductive reasoning ability questions by paying close attention and reading in detail the example questions. Students must read the example questions more than twice in order to understand the meaning of the example questions for hypothetical-deductive reasoning abilities.

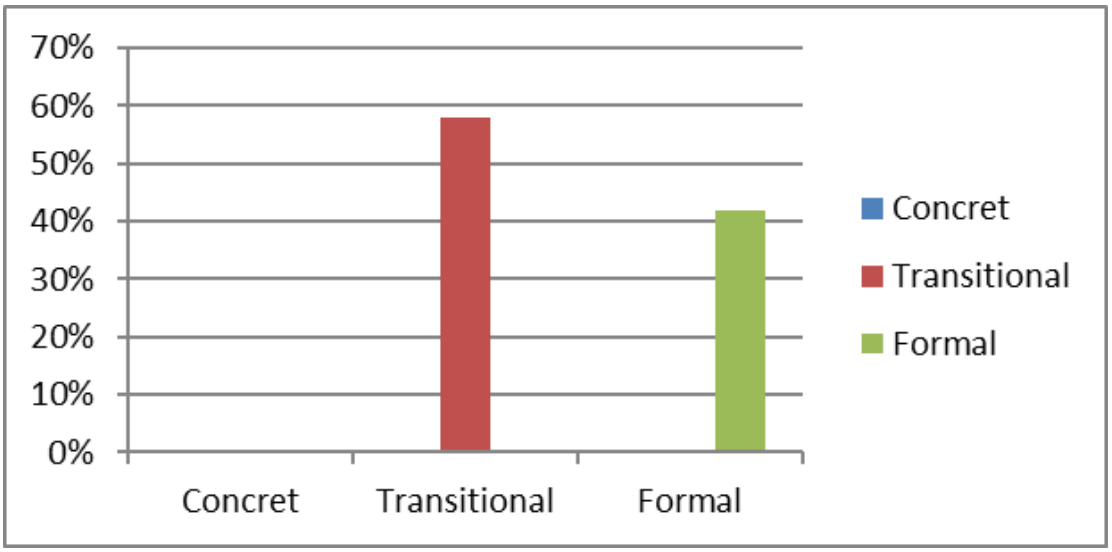

Figure 1. Scientific reasoning patterns of male students.

From the test results, male students fall into the categories of transitional operational patterns and formal operational patterns. Firstly, the transitional operational pattern is the stage when the child's thinking pattern is between the concrete and formal operational stages, namely when the child can demonstrate his ability to think

abstractly but only in a few contexts (Marinda, 2020). Based on the recapitulation of scores, there are 7 male students belonging to the transitional operational pattern with a percentage of 58%. Of course, students who fall into this reasoning pattern are in conflict with the theory of cognitive development presented by Piaget because there is a delay in children's cognitive development, when children should have entered the formal operational stage at the age of 12 (Fauzian, 2020). Therefore, high school students aged around 15-18 years should have entered the formal operational group stage. However, as explained by Yunita et al. (2022), this can happen, because the cognitive development of each individual child is different, some are fast and some are slow and is based on several factors. The two formal operational patterns are stages that begin when the child reaches puberty (around 12 years and above). At this stage, children already have the ability to think abstractly as a whole, do abstract reasoning, and can draw conclusions based on available information (Jariah, 2022). There are 5 male students belonging to the formal operational pattern with a percentage of 42%. Male students who fall into this reasoning pattern are in line with the theory of cognitive development put forward by Piaget, where children aged 12 years and over already have formal operational thinking abilities (Fauzian, 2020).

Table 4. Scientific reasoning skills of female students.

Number	Indicator Scientific Reasoning	Percentage	Category
1	Conservation Reasoning	89%	Very good
2	Proportional Reasoning	82%	Very good
3	Variable Control Reasoning	75%	Good
4	Probabilistic Reasoning	69%	Good
5	Correlation Reasoning	60%	Enough
6	Hypothesis-Deductive Reasoning	80%	Good

Overall, female students' scientific reasoning skills are in the good category. On the conservation reasoning indicator, female students obtained a percentage of 89% (very good). This proves that students are able to understand the questions well, so that students get very high scores on this indicator. In line with the statement of Azmi, Astutik & Subiki (2020), students can be categorized as having good conservation reasoning abilities, if they can maintain their knowledge, even though the appearance of the object changes, the nature of the object remains the same. The percentage of scores obtained by female students on the proportional indicator was 82% in the good category. The results of this research are in line with research by Yunita Ainun Jariah (2022), which states that class XII students can explain their answers correctly and involve the theories they have studied. So quite a lot of students get perfect scores.

The percentage of student scores obtained on variable control indicators is 75% in the good category. As explained by Herman Sopian (2019), students will have good variable control reasoning skills if they are able to design experimental investigations, determine, differentiate and analyze dependent and independent variables. The percentage of probability reasoning scores obtained by female students was 69% in

the good category. The errors experienced by students in solving probability problems are because students often use strategies based on previous experience, beliefs and intuitive strategies (Sharma, 2006). Good probabilistic reasoning abilities can be known if students are able to read data, meaning that students are able to integrate, interpret and look for relationships from information in graphs and tables (Sari, Budayasa & Juniati, (2017).

Similar to male students, the majority of female students answered incorrectly on questions with correlation reasoning indicators. This shows that both of them have difficulty in correlation reasoning. The score obtained on this indicator is a percentage of 60% in the sufficient category. The score obtained was due to students answering questions that were related, but could not determine the keywords needed and could not even understand them (Fauziah, 2020). Based on the test results, the percentage of deductive hypothesis reasoning scores obtained by female students is higher than male students, namely a difference of 6%. Where on this indicator female students obtained a score of 80% in the good category. This shows that women's hypothetical reasoning abilities are higher than men. In line with the research results of Mandella, Suhedar & Setiono (2021), female students outperformed male students on deductive hypothetical reasoning indicators.

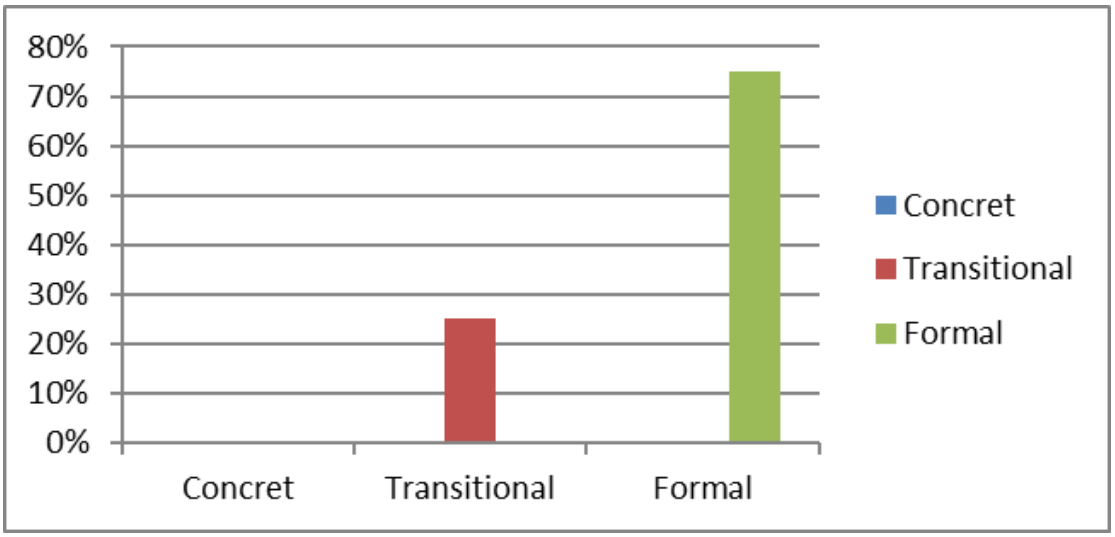

Figure 2. Scientific reasoning patterns of female students.

Firstly, the transitional operational pattern is the stage when the child's thinking pattern is between the concrete and formal operational stages, namely when the child can demonstrate his ability to think abstractly but only in a few contexts (Jariah, 2022). Based on the recapitulation of scores, there are 6 female students belonging to the transitional operational pattern with a percentage of 25%. Of course, students who fall into this reasoning pattern are in conflict with the theory of cognitive development put forward by Piaget. Piaget explained that children aged 12 years to adulthood have entered the formal operational stage (Fauzian, 2020). The two formal

operational patterns are stages that begin when the child reaches puberty (around 12 years and above). There are 18 female students belonging to the formal operational pattern with a percentage of 75%. In line with the cognitive development theory put forward by Piaget, children aged 12 years and over already have formal operational thinking abilities (Fauzian, 2020).

The main factor that causes this difference in ability is the influence of internal and external factors from the students themselves. The first internal factor that causes differences in scientific reasoning skills is brain structure. The differences in the brain structure of men and women are found in the corpus calossum, hypothalamus, inferior parietal lobe and hippocampus. These anatomical differences will have an impact on differences in ways of thinking (Amin, 2018). In terms of brain use, male students tend to use the left brain so they have the ability to think abstractly, logically and analytically. Female students tend to use their right brain, so they will be active linguistically, imaginatively, holistically, perceptively and with some visual abilities (Lestari, 2016).

Differences in the development of students' scientific reasoning skills are influenced by several external factors such as learning strategies, school infrastructure and the school environment. As explained by Hadi et al. (2021), scientific reasoning skills are also influenced by monotonous learning strategies and only focus on conventional learning. The lack of students' level of scientific reasoning skills can be used as a reference for teachers to design efficient and interactive learning processes to improve scientific reasoning skills. One teaching model that can help teachers improve students' scientific reasoning skills is the 5E Learning Model developed by Bybee. The 5E model was developed by Bybee who is the leader of the Biological Science Curriculum Study (BSCS). The 5E model has five phases, namely engage, explore, explain, elaborate, and evaluate (Shofiyah et al., 2013). The facilities and infrastructure provided by the school will also influence the level of students' scientific reasoning skills. During observations, the teacher did not use an LCD when delivering material, because the available LCD projectors were inadequate. Another condition that does not support biology learning is the availability of practical equipment and materials. Therefore, teachers can only carry out simple practicums using materials that are easily accessible. Such poor learning situations can cause learning to be hampered (Utari, Wardana & Damayanti, 2019).

Apart from that, school environmental factors can also influence students' level of scientific reasoning. Based on the results of observations, the difference in the quantity of male and female students means that male students choose to be silent and indifferent during the learning process, while female students are more active in the learning process. The student learning environment can be seen when students study biology in the family, school and community environment, the learning environment greatly influences student learning achievement. We see that education is still optimally charged to teachers in schools, the family environment and community do

not have much of a role in strengthening student learning. In fact, biology learning is actually very closely related to the surrounding environment, even the concepts they get at school should be implemented in the family and community environment. This will be able to improve students' scientific reasoning skills. Therefore, students are also required to be able to apply the theories they learn to everyday life. There are several ways that students can improve their reasoning skills, namely by practicing HOTS questions, forming study groups, and carrying out several investigations/experiments. Because when students are able to design an experiment and present the results of observations well, they will get used to thinking logically (Daryanti et al., 2015).

CONCLUSION

In summary, the study reveals that the scientific reasoning skills of both male and female students fall within the 'good' category. Specifically, among the male students, 7 exhibit transitional operational patterns, while 5 demonstrate formal operational patterns. On the other hand, among the female students, a notable 18 individuals display formal operational patterns, while 6 students exhibit transitional operational patterns. These findings underscore the importance of continued support and enrichment in fostering advanced scientific thinking skills among students, regardless of gender, to further enhance their understanding and application of scientific principles.

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