Hayati: Journal of Education
Vol. 2, No. 1, 2026
e-issn 3109-5100 (Online)
https://jurnal.sinesia.id/index.php/hayati/index

Students' Algebraic Thinking Ability Based on Gender

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Info Article
|**Submitted**: 9 April 2026 |**Revised**: 28 April 2026 |**Accepted**: 2 May 2026
|**Published**: 2 May 2026
How to cite: Iskandar, "Students' Algebraic Thinking Ability Based on Gender", *Hayati: Journal of Education*, Vol. 2, No. 1, 2026, P. 53-65.

ABSTRACT

Algebraic thinking plays a fundamental role in developing students' mathematical reasoning, particularly in recognizing patterns, representing relationships, and generalizing mathematical ideas. This study aims to describe students' algebraic thinking abilities based on gender and to determine whether there is a significant difference between male and female students. The research employed a descriptive comparative method involving eighth-grade students as the sample, selected using total sampling. Data were collected through a written test designed to measure key components of algebraic thinking, including generational, transformational, and meta-global abilities. The data were analyzed using descriptive statistics (percentage, mean, and standard deviation) and inferential statistics through the Mann–Whitney U test. The results indicate that male students' algebraic thinking ability is categorized as moderate, with an average score of 51.48, while female students demonstrate a higher level of ability categorized as good, with an average score of 61.53 (as shown in the results table on page 5). Female students outperform male students across all components of algebraic thinking, particularly in transformational abilities. Statistical analysis reveals a significant difference between the two groups ($p < 0.05$), indicating that gender influences students' algebraic thinking performance. The findings suggest that female students tend to be more accurate, systematic, and careful in solving algebraic problems, while male students are more likely to rely on arithmetic or intuitive approaches. This study highlights the importance of designing instructional strategies that support the development of algebraic thinking for all students while considering gender differences. Further research is recommended to explore effective teaching approaches that enhance students' algebraic thinking skills comprehensively.

Keywords: *ability, algebraic thinking, gender.*

Introduction

Mathematical thinking ability is a person's capacity to investigate and examine problems systematically in order to generate ideas or strategies to solve them logically (Amerom, 2002). Mathematical thinking involves reasoning, identifying relationships, forming generalizations, and applying concepts in problem-solving situations. These abilities are essential for students to understand mathematics meaningfully rather than merely performing procedural computations. Many mathematics topics can be used to describe students' mathematical thinking abilities. According to the National Council of Teachers of Mathematics (2000), there are five content standards in mathematics: numbers and operations, algebra, geometry, measurement, and data analysis and probability. Among these standards, algebra is considered a central strand that supports students' ability to generalize patterns, represent relationships, and construct mathematical models. At the secondary school level, mathematics learning particularly emphasizes the development of algebraic thinking and geometric thinking as foundational competencies for advanced mathematical learning. Carolyn Kieran (2004) explained that algebraic thinking can be interpreted as sa quantitative approach emphasizing general relational aspects without initially using symbols, but which ultimately supports the introduction and development of formal algebraic reasoning.

Students are constantly involved in mathematics learning activities that demonstrate their ability to identify structures, estimate, verify, think hypothetically, understand cause–effect relationships, comprehend abstract concepts, and make generalizations (Murtiyasa, 2015). These activities require students to analyze patterns, recognize relationships, and generalize findings, which are core components of algebraic thinking. Algebraic thinking enables students to transition from arithmetic reasoning to generalized mathematical reasoning. Therefore, algebraic thinking is an essential and fundamental component of mathematical thinking ability (Hayati, 2013). However, in practice, students often experience difficulties in developing algebraic thinking skills, particularly in identifying patterns, expressing generalizations, and representing relationships symbolically. Learning innovations and the use of technology-based learning resources are considered important to support students' mathematical thinking development. Problem-based learning assisted by digital tools can improve students' mathematical literacy and encourage them to construct mathematical ideas actively (Putri, 2025). In addition, educational supervision and technology-based learning environments also play an important role in supporting the development of higher-order thinking skills, including algebraic thinking, through structured and meaningful learning experiences (Ristamala & Khulasoh, 2026).

Besides instructional factors, students' mathematical thinking ability can also be influenced by individual characteristics, one of which is gender. Gender is frequently identified as a factor affecting cognitive development, learning preferences, and problem-solving strategies (Cvencek et al., 2011). Differences in gender may influence how students process information, analyze problems, and construct mathematical reasoning. According to Krutetzki (in Nafi'an, 2011), female students tend to excel in accuracy, precision, thoroughness, and carefulness. This perspective suggests that females may have advantages in certain aspects of thinking compared to males. Similarly, Kartono (in Ningrum & Rosyidi, 2013) stated that females are generally more accurate and more detailed in observing something than males. Meanwhile, Dagun (in Ningrum & Rosyidi, 2013) argued that differences in abilities between males and females are influenced by differences in their ways of thinking. These differences may lead to variations in students' algebraic thinking ability, particularly in recognizing patterns, forming generalizations, and solving algebraic problems.

Although many studies have discussed mathematical thinking and algebraic thinking, most research focuses on learning models, instructional media, or mathematical literacy improvement (Putri, 2025; Ristamala & Khulasoh, 2026). Research that specifically examines algebraic thinking ability based on gender differences is still limited, especially in the context of secondary school students. In addition, previous studies tend to emphasize learning outcomes rather than describing in depth how male and female students demonstrate algebraic thinking processes. This indicates a research gap regarding the description and comparison of students' algebraic thinking ability based on gender. Therefore, it is important to conduct a study that explores how male and female students demonstrate algebraic thinking and whether there are significant differences between them.

Based on these perspectives, the researcher is interested in conducting a study entitled "Students' Algebraic Thinking Ability Based on Gender." The objectives of this study are as follows: (1) To describe male students' algebraic thinking ability. (2) To describe female students' algebraic thinking ability. (3) To determine whether there is a significant difference in algebraic thinking ability between male and female students.

Research Methods

This study employed a descriptive comparative method to examine differences in students' algebraic thinking ability based on gender. The descriptive approach was used to provide a detailed overview of students' algebraic thinking ability, while the comparative approach aimed to compare the performance of male and female students. This method was considered appropriate because the study did not involve treatment or experimental manipulation but focused on describing and comparing existing conditions among students.

The population of this study consisted of all eighth-grade students at the selected junior high school. The eighth grade was chosen because algebra is formally introduced and intensively developed at this level, making it suitable for measuring students' algebraic thinking ability. The sample of this study included all students in the selected grade, both male and female students. Total sampling was employed, meaning that all members of the population were included as research participants. This sampling technique was selected to ensure that the data represented the entire population and to allow for a more accurate comparison between male and female students' algebraic thinking ability.

Data were collected using a written test designed to measure students' algebraic thinking ability on algebra material. The test items were constructed to assess several aspects of algebraic thinking, including identifying patterns, representing relationships, generalizing mathematical ideas, and solving algebraic problems. Each student's response was scored according to predetermined scoring guidelines to ensure consistency and objectivity. The total score obtained by each student reflected their level of algebraic thinking ability. The obtained scores were then interpreted using five categories: very low (0–20), low (21–40), moderate (41–60), good (61–80), and very good (81–100), following the criteria proposed by Irvaniyah and Akbar (2014). These categories were used to provide a clearer description of students' algebraic thinking ability levels.

Data analysis was conducted using both descriptive and inferential statistical techniques. Descriptive statistics were used to summarize and describe students' algebraic thinking ability. These included percentage, mean, and standard deviation. The percentage was calculated to determine the proportion of students in each ability category, allowing the researcher to identify the distribution of students' algebraic thinking ability levels. The mean score was used to describe the average algebraic thinking ability of students overall as well as by gender. Meanwhile, the standard deviation was computed to determine the level of variation in students' scores, indicating whether students' abilities were relatively homogeneous or varied widely.

Furthermore, inferential statistical analysis was conducted to determine whether there was a significant difference between male and female students' algebraic thinking ability. Prior to conducting the difference test, assumption tests were performed, including the normality test and homogeneity test. The normality test was used to determine whether the data were normally distributed, while the homogeneity test was conducted to examine whether the variances of the two groups were equal. ll statistical analyses were performed using IBM SPSS Statistics. If the data met the assumptions of normality and homogeneity, an independent samples t-test was applied to compare the mean scores of male and female students. However, if the data did not meet these assumptions, the Mann–Whitney U test was used as a non-parametric alternative. The Mann–Whitney U test does not require normally distributed data or homogeneity of variance, making it appropriate for comparing two independent groups under non-normal conditions. The results of this inferential analysis were used to determine whether there was a statistically significant difference between male and female students' algebraic thinking ability.

Results and discussion

The descriptive statistics of students' algebraic thinking scores based on gender are presented in Table 1.

Table 1. Algebraic Thinking Scores Between Male and Female Students

Gender	N	Highest	Lowest	Mean	SD	Very Low (%)	Low (%)	Moderate (%)	Good (%)	Very Good (%)
Male	130	86.67	16.67	51.48	19.44	10.00	17.69	36.92	28.46	6.92
Female	154	94.44	16.67	61.53	17.83	1.95	7.79	34.42	35.06	20.78

The results showed that the highest algebraic thinking score for male students was 86.67, while the lowest score was 16.67. From 130 male students, the mean score was 51.48 with a standard deviation of 19.44, which falls into the moderate category. Most male students were classified in the moderate category, accounting for 36.92% of the total sample, followed by the good category (28.46%), low category (17.69%), very low category (10.00%), and very good category (6.92%). These findings indicate that male students' algebraic thinking ability was generally at a moderate level, with only a small proportion achieving a very good level. Furthermore, the comparison of average scores across algebraic thinking components revealed that the meta-global level ability had the lowest mean score compared to generational and transformational abilities.

For female students, the mean algebraic thinking score was 61.53, with the highest score of 94.44 and the lowest score of 16.67 among 154 students. The standard deviation was 17.83, and the overall mean score fell into the good category. Most female students were in the good category (35.06%), followed closely by the moderate category (34.42%), while 20.78% of students achieved the very good category. Only a small proportion of female students were in the low (7.79%) and very low (1.95%) categories. These results indicate that female students generally demonstrated better algebraic thinking ability compared to male students. In terms of algebraic thinking components, the transformational ability had the highest mean score (68.40), followed by meta-global ability (58.51) and generational ability (57.68).

A comparison between male and female students showed that both groups had the same lowest score (16.67), but female students achieved a higher maximum score (94.44) than male students (86.67). The average score of female students (61.53) was higher than that of male students (51.48), with a difference of 10.05 points. However, male students had a larger standard deviation (19.44) compared to female students (17.83), indicating greater variability in male students' performance. The comparison of algebraic thinking components also revealed that female students outperformed male students in generational, transformational, and meta-global abilities.

To determine whether the difference between the two groups was statistically significant, a Mann–Whitney U test was conducted. The results showed a significance value of 0.000, which was lower than the significance level of 0.05. This indicates that the alternative hypothesis was accepted and the null hypothesis was rejected. Therefore, it can be concluded that there was a statistically significant difference between male and female students' algebraic thinking abilities, with female students demonstrating higher performance overall.

The mean score of male students' algebraic thinking ability was 51.48, which falls into the moderate category. This result indicates that male students demonstrated some aspects of algebraic thinking; however, their ability had not yet developed optimally. In general, most male students tended to rely on arithmetic reasoning rather than algebraic reasoning when solving the given problems. They frequently attempted to compute numerical results directly instead of identifying patterns, expressing relationships, or generalizing solutions using variables. As a result, their responses often reflected procedural calculations rather than conceptual understanding of algebraic structures.

Although the test items were designed to measure algebraic thinking, many male students experienced difficulty in formalizing their ideas using meaningful symbols. When problems involved visual representations such as patterns, shapes, or diagrams, male students rarely used letters or variables to describe unknown quantities. Instead, they tended to count specific values or substitute particular numbers into the problem. This approach limited their ability to generalize patterns and represent relationships mathematically. Consequently, they encountered difficulties when transforming pictorial or contextual information into formal algebraic equations. Algebraic thinking requires students to express general relationships using variables and to represent unknown quantities symbolically, but these skills were not consistently demonstrated by male students.

In tasks requiring algebraic modeling, some male students showed misconceptions related to variables and algebraic expressions. For example, when dealing with expressions such as $2a + 2$, several students simplified the expression to 4 by assigning a specific value to the variable a. They assumed that the expression represented a single numerical result rather than a general form. This indicates that students had limited understanding of variables as generalized numbers and struggled to interpret algebraic expressions as representations of relationships. Such misconceptions also suggest that students focused on obtaining numerical answers rather than understanding algebraic structures.

Male students demonstrated some tendencies in abstract reasoning when engaging with algebraic tasks, particularly when problems were presented in symbolic form. Previous studies indicate that algebraic thinking develops from students' ability to generalize patterns, manipulate symbols, and interpret relationships among variables rather than relying solely on arithmetic procedures (Levin & Walkoe, 2022). However, in practice, only a small number of male students effectively used visualization strategies to construct algebraic representations. Most students still relied on arithmetic calculations even when the problems required generalization. This finding aligns with recent research showing that students often demonstrate partial algebraic reasoning and depend on procedural strategies rather than structural understanding when solving algebraic problems (Kurniyasih & Nugraheni, 2023).

Male students showed some evidence of algebraic thinking in transformational tasks, particularly when problems were already presented in abstract symbolic form. In such cases, students were able to manipulate algebraic expressions and apply procedural rules. However, several students still relied on trial-and-error strategies, such as substituting values into equations instead of solving them using systematic algebraic transformations. This behavior indicates partial procedural understanding but limited conceptual reasoning. Recent studies emphasize that algebraic thinking requires students to connect symbolic manipulation with conceptual understanding of variable relationships and generalization processes (Giyanti et al., 2024).

Overall, the generational, transformational, and meta-global components of algebraic thinking among male students were categorized as moderate. In the generational aspect, many students struggled to form algebraic expressions from patterns or contextual situations. This difficulty is consistent with recent findings that students often experience challenges in generalization and variable interpretation when transitioning from arithmetic to algebraic thinking (Safitri & Masduki, 2023). In the transformational aspect, although some students could manipulate algebraic expressions, their procedures were often incomplete or inconsistent. In the meta-global aspect, students had difficulty understanding relationships among variables and interpreting algebraic models in broader contexts. These findings indicate that male students' algebraic thinking ability had not yet developed comprehensively.

Many male students also experienced difficulty translating verbal statements into algebraic models. They tended to misinterpret problem statements or omit important information when forming equations. In addition, students often showed limited accuracy and carefulness when solving algebraic tasks, resulting in computational errors and incorrect representations. These difficulties contributed to the moderate average score of male students' algebraic thinking ability, indicating that further instructional support is needed to strengthen students' understanding of variables, symbolic representation, and algebraic generalization.

The mean score of female students' algebraic thinking ability was 61.53, which falls into the good category. This result indicates that, in general, female students demonstrated better algebraic thinking ability compared to male students. However, although the average score was categorized as good, a closer examination of students' responses showed that many female students were still operating at an informal level of algebraic reasoning. This means that students were able to understand patterns and relationships, but they had not fully generalized these relationships into formal algebraic expressions using variables consistently. In several cases, female students expressed solutions using words or step-by-step numerical reasoning rather than concise symbolic representations. This indicates that their algebraic thinking had begun to develop but had not yet reached a fully formal level.

Female students generally demonstrated stronger verbal abilities, which supported their understanding of problem statements and their ability to construct mathematical models. They tended to read questions more carefully, identify known and unknown information, and interpret relationships between quantities more accurately. This careful reading helped them avoid misinterpretation of problem contexts. As a result, female students were more successful in translating verbal problems into algebraic expressions. Although fewer female students visualized problems using diagrams or sketches, most of them were still able to model problems algebraically by identifying relationships among quantities directly from the text. This suggests that female students relied more on verbal reasoning than visual-spatial reasoning when developing algebraic models.

However, in problem-solving tasks, some female students still relied on arithmetic approaches. They often focused on calculating numerical answers step by step rather than expressing general relationships using variables. For example, when faced with pattern-based problems, some students calculated successive values instead of forming general formulas. This indicates that although female students were able to construct algebraic representations, they sometimes preferred procedural arithmetic strategies. This tendency suggests that their algebraic thinking was still developing and not yet fully generalized.

Based on the analysis of algebraic thinking components, the generational and meta-global abilities of female students were categorized as moderate, while transformational ability was categorized as good. The generational aspect refers to students' ability to form algebraic expressions from patterns, diagrams, or contextual problems. In this aspect, some female students were able to identify relationships but still had difficulty expressing them in generalized symbolic form. This finding is consistent with previous studies indicating that students often recognize patterns but experience challenges in translating them into formal algebraic representations (Levin & Walkoe, 2022; Safitri & Masduki, 2023; Jamil et al., 2025). The meta-global aspect refers to students' ability to understand relationships among variables and interpret algebraic structures in broader contexts. In this component, several students were able to interpret relationships correctly but still lacked consistency in generalizing them. Previous research also reports that students frequently demonstrate partial relational understanding when working with variables and struggle to connect representations across contexts

(Levin & Walkoe, 2022; Jamil et al., 2025). Meanwhile, transformational ability was categorized as good, indicating that female students were relatively able to manipulate algebraic expressions and apply symbolic procedures. **This result aligns with studies showing that students tend to perform better in symbolic manipulation than in generalization and relational reasoning in algebraic thinking (Safitri & Masduki, 2023; Jamil et al., 2025).**

Meanwhile, transformational ability was categorized as good. Transformational tasks involve manipulating algebraic expressions, simplifying equations, and performing algebraic operations such as combining like terms or isolating variables. These tasks require procedural accuracy, attention to detail, and careful calculation. Female students demonstrated strengths in these areas, as they tended to work more carefully and systematically. They showed better performance in applying algebraic rules and maintaining consistency in symbolic manipulation. This careful and detailed approach allowed female students to avoid many common algebraic errors, contributing to their higher performance in transformational tasks.

In algebraic thinking, students must recognize mathematical structures, consider relationships among quantities, and generalize patterns into symbolic form. Female students' careful and systematic approach supported their ability to understand problem requirements more thoroughly. Their strong verbal skills also helped them interpret contextual problems and construct algebraic models more accurately. Although some students still relied on arithmetic reasoning, many were able to identify relationships and perform algebraic transformations correctly. These strengths contributed to female students' overall algebraic thinking ability being categorized as good, even though some aspects, particularly generalization and meta-global reasoning, still required further development.

The comparison between male and female students showed that the mean algebraic thinking score of female students was higher than that of male students. Female students obtained an average score of 61.53, while male students achieved an average score of 51.48, resulting in a difference of 10.05 points. This difference indicates that female students demonstrated better performance in algebraic thinking tasks. Statistical testing further confirmed that this difference was significant, meaning that the variation in scores between male and female students was not due to chance but reflected a meaningful difference in their algebraic thinking ability. This finding suggests that gender may play a role in influencing students' approaches to understanding and solving algebraic problems.

Although both male and female students received the same learning materials, instructional time, and classroom environment, their approaches to solving problems tended to differ. These differences can be associated with variations in verbal ability, spatial ability, and thinking strategies. Students with stronger verbal abilities tend to better understand problem statements, identify known and unknown information, and interpret relationships between quantities. This ability helps students translate contextual problems into algebraic models more effectively. Female students generally demonstrated these characteristics, as they tended to read questions more carefully, interpret information systematically, and construct mathematical representations based on relationships rather than isolated numbers.

Algebraic thinking requires students to model situations using variables, recognize relationships among quantities, and transform algebraic expressions accurately. These processes demand precision, logical reasoning, and careful manipulation of symbols. Female students generally showed greater accuracy and carefulness when solving algebraic problems. They were more likely to check their work, follow step-by-step procedures, and maintain consistency when manipulating algebraic expressions. This careful approach reduced computational errors and improved their ability to perform algebraic transformations correctly. As a result, female students demonstrated stronger performance, particularly in tasks involving symbolic manipulation and equation solving.

In contrast, male students tended to rely more on intuitive or arithmetic strategies when solving problems. They often attempted to substitute numerical values or use trial-and-error approaches rather than forming general algebraic relationships. Although male students sometimes showed strengths in visualizing patterns or understanding abstract representations, these abilities were not consistently applied in constructing algebraic models. Some male students also tended to work more quickly, which occasionally led to inaccuracies in symbolic manipulation. These tendencies contributed to lower overall performance in algebraic thinking tasks compared to female students.

Furthermore, algebraic thinking emphasizes relational understanding, where students must focus on how quantities are connected rather than simply calculating numerical results. Female students were generally more attentive to these relationships and more consistent in expressing them using algebraic symbols. Their ability to interpret problem contexts carefully and represent them mathematically supported stronger generational and transformational thinking processes. These characteristics contributed to female students' higher algebraic thinking scores. Therefore, the significant difference between male and female students' algebraic thinking ability can be explained by differences in verbal comprehension, accuracy, carefulness, and problem-solving strategies, which collectively influenced their performance in algebraic thinking tasks.

Conclusion

Based on the results of the study on students' algebraic thinking ability based on gender, it can be concluded that male students' algebraic thinking ability was in the moderate category. Their generational ability was categorized as moderate, transformational ability was also moderate, and meta-global level ability was likewise moderate. In contrast, female students' algebraic thinking ability was categorized as good, with generational ability in the moderate category, transformational ability in the good category, and meta-global level ability in the moderate category. The analysis also revealed a significant difference between male and female students' algebraic thinking scores, with female students obtaining a higher mean score than male students.

Based on these findings, it is recommended that students continue practicing and developing their algebraic thinking ability, particularly through exercises involving algebraic modeling that support mathematical problem solving. Teachers are also expected to design learning activities that stimulate students' algebraic thinking, especially in the aspects of generational ability and meta-global level ability. In addition, schools should create learning environments and activities that enhance students' mathematical thinking in general and algebraic thinking in particular. Future researchers are encouraged to conduct further studies to explore more effective instructional strategies for improving students' algebraic thinking ability while considering gender differences.

Suggestion

Based on the findings of this study, several suggestions are proposed. Students are encouraged to improve their algebraic thinking ability through regular practice, particularly in constructing algebraic models and identifying relationships among variables. Teachers are advised to design instructional activities that emphasize generational and meta-global aspects of algebraic thinking, such as translating verbal problems into algebraic expressions, recognizing patterns, and generalizing mathematical relationships. In addition, teachers should provide varied problem-solving tasks that promote both conceptual understanding and symbolic reasoning. Schools are also expected to support the development of students' mathematical thinking by facilitating learning environments that encourage exploration, discussion, and collaborative problem solving. Future researchers are recommended to conduct further studies focusing on instructional strategies that effectively enhance algebraic thinking ability while considering gender differences and other relevant factors.

Acknowledgements

The author would like to express sincere gratitude to all parties who contributed to the completion of this study. Appreciation is extended to the school principal and mathematics teachers for their support and permission to conduct the research. The author is also grateful to the students who participated in this study for their cooperation and enthusiasm during data collection. Special thanks are given to colleagues and reviewers for their valuable suggestions and constructive

feedback, which helped improve the quality of this research. Finally, the author acknowledges all individuals who provided assistance, encouragement, and support throughout the research process.

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