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Female Students' Mathematical Argumentation Ability Based on Self-Efficacy Level

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Abstract

This study aims to investigate the mathematical argumentation abilities of female students based on their levels of self-efficacy. Mathematical argumentation is crucial in math education for mastering concepts and developing higher-order thinking skills. Self-efficacy relates to an individual's confidence in completing math tasks, including argumentation The research employs a quantitative approach, collecting data from 36 students in the Mathematics Education Program. Data was gathered through a self-efficacy questionnaire and math tasks related to statistics that assess students' mathematical argumentation. The findings indicate that mathematical argumentation abilities vary across different levels of self-efficacy. . Students with high self-efficacy do not always have strong mathematical arguments, and vice versa. The level of self-efficacy in students does not determine the strength of the mathematical arguments presented by students.

Keywords*: Mathematical argumentation, Self-efficacy, Mathematics education.*

Abstrak

Penelitian ini bertujuan untuk mengetahui kemampuan argumentasi matematis mahasiswa perempuan berdasarkan tingkat self-efficacy. Argumentasi matematis penting dalam pembelajaran matematika untuk menguasai konsep dan mengembangkan keterampilan berpikir tingkat tinggi. *Self-efficacy* berkaitan dengan keyakinan individu dalam menyelesaikan tugas matematika, termasuk dalam hal argumentasi. Studi ini menggunakan pendekatan kuantitatif dengan mengumpulkan data dari 36 mahasiswa Program Studi Pendidikan Matematika. Data diperoleh dari kuesioner *self-efficacy* dan tugas matematika terkait statistika yang menagih argumentasi matematis mahasiswa. Berdasarkan hasil penelitian, kemampuan argumentasi matematis berbeda pada setiap tingkat *self-efficacy.* Mahasiswa dengan self-efficacy tinggi tidak selalu memiliki argumentasi matematis kuat begitupun sebaliknya. Tingkat self-efficacy mahasiswa tidak menentukan kuat atau tidaknya argumentasi matematis yang dikemukakan mahasiswa.

Kata kunci: Argumentasi matematis, *Self-efficacy*, Pendidikan matematika.

INTRODUCTION

Argumentation is defined as a collection of statements used to support, justify, or refute an idea using reasonable premises (Damer, 2008). Menurut Resmi et al. (2021), mathematical argumentation is the process of conveying a mathematical concept, rule, or principle with one's own understanding while maintaining the established mathematical symbols and notations. According to the National Council of Teachers of Mathematics (NCTM), mathematical argumentation is an important component in achieving mathematics learning goals because it can help individuals master mathematical concepts and develop high-level thinking skills (Wirawan et al., 2023). Studies on the construction of mathematical argumentation often focus on materials such as algebra, geometry, and statistics (Dogan, 2022; Jagadianti & Rosyidi, 2023; Sukirwan et al., 2020). Mathematical argumentation plays a role in presenting in-depth and detailed reasons by integrating critical thinking, data support, and relevant theories in solving mathematical problems (Putra et al., 2022).

In general, there are several components of argumentation to help detail and understand how mathematical arguments are constructed and evaluated. According to Toulmin (2003), the components of argumentation are claims, grounds, warrants, backings, qualifiers, and rebuttals. Claims are defined as statements or propositions that are to be proven or supported in an argument (Kartika et al., 2024). Grounds are defined as information or evidence used to support a claim, while warrants are defined as the logical relationship between grounds and claims (Walton, 2004). In addition, there are three additional components of argumentation, namely backings as additional information or evidence that supports warrants, qualifiers as limitations that clarify claims, and rebuttals as counterarguments that contradict claims (Arifin et al., 2023). Argumentation plays a significant role in developing deeper mathematical understanding and encouraging problem-solving skills (Siregar et al., 2024). However, the development of mathematical argumentation skills can be influenced by various factors, including gender and self -efficacy.

Bandura (1994) states self-efficacy as "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives." Based on this sentence, self-efficacy is defined as an individual's belief in their ability to succeed in certain situations, and how that belief affects their behavior and achievements. According to Amar (2024)) self-efficacy is defined as a belief in one's own ability to succeed in a particular task. The high attention to mathematics learning has given rise to a deep understanding of the role of self-efficacy. Self-efficacy influences an individual's thoughts, feelings, motivation, and behavior (Rahmi et al., 2017). Based on the research results of Schunk & DiBenedetto (2016) and

Schunk & Usher (2019) self-efficacy has been shown to be one of the strongest motivational factors in the mathematics learning process. Self-efficacy is also an important factor that influences a person's involvement and performance in mathematics (Annisa et al., 2024).

Individual confidence in their ability to complete mathematical tasks can be understood through the self-efficacy dimension. There are 3 dimensions of self-efficacy, namely magnitude, strength, and generality (Bandura et al., 2006). Magnitude refers to the level of difficulty felt by a person in completing a task (Islamiyah et al., 2022). In other words, when individuals are faced with tasks with varying levels of difficulty, their level of self-efficacy will also vary. They will tend to complete tasks that are in accordance with their abilities. Strength reflects a person's level of confidence in completing a particular task, so this dimension is related to the enthusiasm and level of difficulty faced by the individual (‘Aini, 2020). Individuals with high self-efficacy tend to remain persistent and do not give up easily when facing obstacles, even when facing various challenges. Conversely, individuals with low self-efficacy are more easily distracted by minor obstacles when working on tasks or facing challenges. Generality refers to the extent to which individuals believe in their own abilities (Mukti & Tentama, 2020). This is related to how much confidence an individual has in their ability to complete various tasks and achieve success in various conditions. Ananda & Wandini (2022) stated that generality shows that individuals who believe in their mathematical abilities tend to be more motivated to face challenges and strive to achieve success in learning mathematics.

Educators' self-efficacy can directly affect the quality of mathematics teaching and the development of students' thinking (Perera & John, 2020). Various studies have shown that the role of teachers is very important in student success in the classroom (Óskarsdóttir et al., 2020; Özdemir, 2019; Taylor & P. Ringlaben, 2012) The mathematical beliefs and skills possessed by teachers will have an impact on students' learning experiences on the material taught in the future (Nasution & Pasaribu, 2023). In addition, the context of mathematics education at the college level is the basis for a deeper understanding of mathematics and the foundation of knowledge that will be taught to students. Therefore, teachers' mathematical beliefs and skills affect not only the quality of current teaching but also provide a solid foundation for students' further understanding of mathematics.

Gender differences can affect an individual's cognitive style and problem-solving strategies (Hanggara et al., 2022). These differences often extend to the level of self-efficacy and skills in constructing mathematical arguments. Krutetskii dalam Naja et al. (2021), stated that women often have advantages in thoroughness, accuracy, precision, and careful thinking. Good verbal skills also allow women to formulate more coherent and clear arguments (Babys, 2020).

Previous research related to self-efficacy in the context of mathematical argumentation conducted by Kurniawan et al. (2023) which focused on investigating students' mathematical argumentation abilities when proving mathematical statements based on their self-efficacy. The method used was qualitative with a case study design. In addition, research related to self-efficacy was also conducted by Smit et al. (2023) which broadly aims to obtain a detailed picture of how self-efficacy influences an individual's ability to think mathematically. The method used is a quantitative method with a multi-level modeling approach. Previous studies have provided an initial picture of the relationship between self-efficacy and mathematical argumentation. However, there are still many gaps that need to be filled in order to gain a more comprehensive and in-depth understanding. A better understanding of this relationship can provide deeper insights into improving the argumentation abilities of prospective teacher students. Based on this description, the researcher is interested in knowing the mathematical argumentation abilities of female students based on their level of self-efficacy.

RESEARCH METHOD

This study uses a descriptive method with a quantitative approach. This type of research attempts to describe facts, conditions, and phenomena that occur factually, systematically, and accurately (Sugiyono, 2015). This approach is a statistical analysis approach to visualize, summarize, and analyze quantitative data (Umami, 2023). Data were collected through a survey method by distributing questionnaires and mathematical argumentation tasks to a number of participants. A total of 36 female Mathematics Education students at a state university in Surabaya were selected as respondents using random sampling techniques. The selected female students have different levels of self-efficacy. Respondents consisted of active students from the 2022 and 2020 classes. This research was conducted in October 2023.

The research instrument involved ten questionnaire questions related to self-efficacy and five mathematical assignments related to statistics distributed via Google Forms. The questionnaire to measure self-efficacy consisted of statements with answer options including disagree, disagree, agree, and strongly agree. In addition, the mathematical assignment to assess mathematical argumentation skills consisted of short questions with complex multiple-choice answers related to mathematical problems. The aspects analyzed included three dimensions of self-efficacy (Bandura et al., 2006) and mathematical argumentation components according to S. E. Toulmin, (2003). The following indicators of mathematical argumentation components used for scoring are described in Table 1.

Tabel 1. Mathematical Argumentation Component Indicators

Component	Indicator
Claim (C)	State an opinion
Grounds (G)	Provide evidence or facts that support the claim
Warrants (W)	Connect the claim and grounds in the form of applicable formulas/rules that justify the claim
Backings (B)	Provide support for warrants
Qualifier (Q)	Show the type of rational power to be associated with the claim based on its relationship to grounds, warrants, and backings.
Rebuttals (R)	State the exception conditions that may make the claim no longer standard

S. E. Toulmin, (2003)

Meanwhile, self-efficacy indicators related to the three dimensions (Bandura et al., 2006) are described in Table 2 below.

Table 2. Self-efficacy Indicators

Dimension	Indicator
Magnitude (difficulty level)	Solving difficult problems
	Finding ways to solve problems when something is blocking goals
	Easy to focus on goals and achieve goals
Strength	Coping efficiently when unexpected things happen
	Knowing how to deal with unexpected situations
	Able to deal with tasks beyond one's ability
	Remaining calm when faced with difficulties
Generality	Finding multiple solutions when faced with problems
	Thinking of solutions in difficulties
	Persisting in difficult situations

Bandura et al., (2006)

Then, the assessment scale used for the self-efficacy questionnaire uses a Likert scale developed by Rensis Likert (Mumu et al., 2022). The Likert scale is used to measure the extent to which students agree or disagree with a particular statement. Each response is related to a statement or expression of attitude support expressed in the form of words in Table 3 as follows.

Table 3. Likert Self-efficacy Scale

Criteria	Scale
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

Likert (Mumu, et al. (2022))

The level of self-efficacy of each student is then grouped into three based on the number of scores obtained which are then converted into high, medium, and low categories. The following score interpretation criteria adapted from Ramadhani (2020) are shown in Table 4.

Table 4. Score Interpretation Criteria

Tingkat Self-efficacy	Kriteria
High	self-efficacy score $\geq \bar{X} + SD$
Medium	$\bar{X} + SD >$ self-efficacy score $> \bar{X} - SD$
Low	self-efficacy score $\leq \bar{X} - SD \geq \bar{X} + SD \leq \bar{X} - SD$

Ramadhani (2020)

Meanwhile, students' answers to the mathematical argumentation task will be analyzed in depth to identify the correctness of students' answers and meet the predetermined indicators of mathematical argumentation ability. Then, descriptive analysis will be used to describe students' mathematical argumentation ability quantitatively. Descriptive statistics such as mean, standard deviation, and frequency will be presented to provide a more comprehensive picture of the distribution of students' mathematical argumentation ability at each level of self-efficacy.

RESULTS AND DISCUSSION

Before further analysis of mathematical argumentation ability is conducted, it is important to know the distribution and characteristics of self-efficacy among students who are the subjects of this study. Therefore, descriptive statistical analysis is conducted to provide an overview of the level of student self-efficacy. The results of descriptive statistics will be used as a basis for

further analysis in this study. The following descriptive statistical data on student self-efficacy are shown in Table 5.

Table 5. Descriptive Statistics of Students' Self-efficacy

Descriptive Statistics	***Self-efficacy***
Minimum Value	0
Maximum Value	40
Average	30,5
Mode	30
Standard Deviation	3,5

Based on Table 5, it is known that the average self-efficacy score of students is 30.5 with a minimum value of 0 and a maximum value of 40. Furthermore, this data is analyzed in more depth to identify the frequency distribution of students according to their self-efficacy levels. Data on the level of self-efficacy of Mathematics Education students are presented in Table 6 below.

Table 6. Student Self-efficacy Score Frequency

Tingkat *self-efficacy*	**Frequency**	**Percentage**
High	6	17%
Medium	22	61%
Low	8	22%

Table 6 shows that 6 students are in the high self-efficacy category or if presented it becomes 17%. In the medium category, there are 22 students or 61% of the total. In the low category, the frequency of students is 8 with a percentage of 22%. Based on this, it can be seen that the majority of students, namely 22 out of 36 people, have a level of self-efficacy in the medium category. This means that some students have a fairly strong belief in their abilities, are able to face challenges well, are optimistic in achieving success, and have sufficient perseverance in solving problems. Furthermore, to further analyze how mathematical argumentation skills vary based on the level of self-efficacy, Table 7 is presented. This table presents the frequency of students who are able to meet the predetermined argumentation components.

Table 7. Frequency of Student Argumentation Components

Components	Frequency	Percentage
Claim (C)	17	47%
Grounds (G)	30	83%
Warrants (W)	16	44%
Backings (B)	15	42%
Qualifier (Q)	14	38%
Rebuttals (R)	5	14%

Based on Table 7, it appears that most students were successful in providing reasons (grounds) to support their statements. As many as 30 students or 83% were able to formulate the ground correctly. This shows that the majority of students have a good understanding of the importance of evidence to support their initial statements. Furthermore, the analysis of students' mathematical argumentation construction shows a significant difference in the ability to fulfill the components of argumentation based on the level of self-efficacy. Diagram 1 presents the frequency of students who fulfill each component of mathematical argumentation at each self-efficacy.

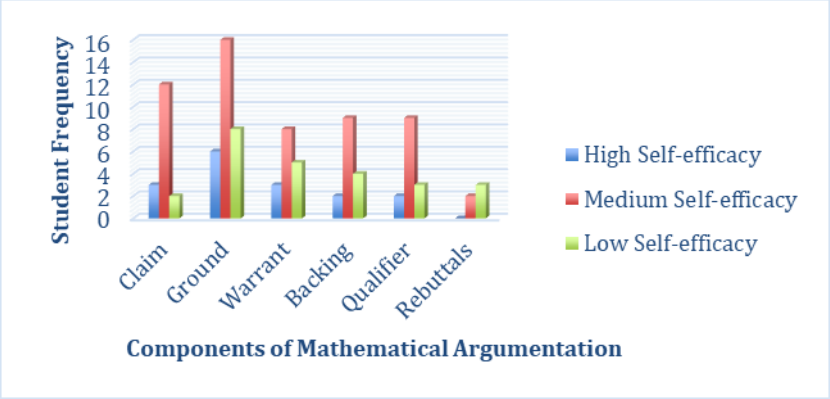

Diagram 1. Frequency of Students with Different Levels of Self-efficacy

Based on Diagram 1, students with high self-efficacy tend to formulate mathematical argumentation components such as ground with higher frequency compared to other components. Meanwhile, students with moderate self-efficacy show better ability in formulating various argumentation components as a whole including claim, ground, warrant, backing, qualifier, and rebuttals. Students with low self-efficacy, although able to formulate some mathematical argumentation components, show lower frequency.

The results showed that students with high self-efficacy showed better ability in formulating ground (6 people). However, they had less frequency in formulating claim (3 people), warrant (3 people), backing (2 people), and qualifier (2 people). This indicates that even though they have high self-efficacy, they may still face challenges in consistently compiling some components of mathematical argumentation. In addition, excessive self-confidence can also result in lack of attention to detail or errors in compiling argumentation components. This is in line with research conducted by Sarah et al. (2023) which shows that individuals with high self-efficacy tend to make mistakes in the completion process due to being less careful and in a hurry.

On the other hand, students with moderate self-efficacy showed a higher frequency in formulating various argumentation components. They succeeded in formulating claims (12 people), grounds (16 people), warrants (8 people), backings (9 people), qualifiers (9 people), and rebuttals (2 people). Their ability to compile components more completely shows that they have adequate levels of self-efficacy and better skills in formulating mathematical arguments.

Students with low self-efficacy, despite having the ability to formulate several argumentation components, showed a lower frequency. They were able to formulate claims (2 people), warrants (5 people), backing (4 people), qualifiers (3 people) compared to the medium self-efficacy group. However, they managed to formulate ground (8 people) and rebuttal (3 people) in a relatively better frequency than claims. This indicates that students with low self-efficacy may feel more comfortable with certain components but have difficulty in formulating arguments comprehensively. According to (Bandura, 1994), individuals with low self-efficacy tend to avoid tasks that they consider difficult and focus on aspects that they consider easy. This is also explained by (Afifah & Kusuma, 2021) that individuals with low self-efficacy tend to lose motivation quickly, so they tend to avoid tasks that are considered difficult.

Overall, this study provides in-depth insights into how mathematical argumentation differs across levels of self-efficacy. The results show that self-efficacy plays a significant role in students' mathematical argumentation ability to formulate argumentation components completely and correctly. By understanding this variation, strategic steps can be taken to support the development of mathematical argumentation among mathematics education students, especially by considering their level of self-efficacy. This is important to ensure that all students, regardless of their level of self-efficacy, can reach their full potential in mathematical argumentation ability.

CONCLUSION

Based on the results and discussions that have been carried out, it can be concluded that mathematical argumentation skills at each level of self-efficacy are different. Students with high levels of self-efficacy tend to be better able to formulate the grounds component than other components. Meanwhile, students with moderate self-efficacy have sufficient ability to formulate most of the argumentation components. They are able to compose relatively complete mathematical arguments. Students with low self-efficacy tend to only be able to formulate a few argumentation components well. This indicates that they need additional support to improve their argumentation skills. Further research can be conducted with a longitudinal approach to see the development of students' mathematical argumentation skills along with changes in their levels of self-efficacy.

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