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Correlation between Self-Efficacy and Mathematical Argumentation: A Case Study of Mathematics Education Students

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Abstract

Self-efficacy in the context of mathematical argumentation describes the importance of understanding an individual's belief in forming solid argumentation skills. Mathematical argumentation helps individuals present various opinions to support creative mathematical solutions. This research aims to determine the correlation between self-efficacy and mathematical argumentation among students in the mathematics education program. This study employs a quantitative correlational approach using survey methods to collect data from 41 students in the mathematics education program. Data was obtained from a self-efficacy questionnaire and statistical-related mathematics tasks that assessed students' mathematical argumentation. Based on the research findings, no correlation was found between self-efficacy and mathematical argumentation. 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: self-efficacy, mathematical argumentation, correlation, mathematics education

Abstrak

Self-efficacy dalam konteks argumentasi matematis menggambarkan pentingnya pemahaman terhadap keyakinan individu untuk membentuk keterampilan argumentasi yang solid. Argumentasi matematis membantu individu mengemukakan beragam pendapat untuk mendukung solusi matematis yang kreatif. Penelitian ini bertujuan untuk mengetahui korelasi antara *self-efficacy* dengan argumentasi matematis mahasiswa Program Studi Pendidikan Matematika. Studi ini menggunakan pendekatan kuantitatif korelasional dengan metode survei untuk mengumpulkan data dari 41 mahasiswa Program Studi Pendidikan Matematika. Data diperoleh dari kuesioner *self-efficacy* dan tugas matematika terkait statistika yang menagih argumentasi matematis mahasiswa. Berdasarkan hasil penelitian, tidak ditemukan korelasi antara *self-efficacy* dengan argumentasi matematis. 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: *self-efficacy,* argumentasi matematis, korelasi, pendidikan matematika

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Introduction

The high attention to mathematics learning has led to a deep understanding of the role of self-efficacy. Madhu and Lekha (2021) 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 refers to an individual's belief in their ability to succeed in particular situations and how these beliefs affect their behavior and achievements. Aligns with this, Clemente et al., (2024) state that self-efficacy in mathematics is a key factor in both academic success and career goals within the STEM (science, technology, engineering, and mathematics) domains. Self-efficacy is crucial as it reflects an individual's confidence in their own ability to solve problems, complete assignments, and answer questions in their studies (Nurlinda et al., 2024). Furthermore, self-efficacy influences an individual's thoughts, feelings, motivation, and behavior (Rahmi et al., 2017).

Shahali and Halim (2024) state that, according to social cognitive theory, self-efficacy is the fundamental force driving internal motivation. It is proven in several studies that self-efficacy is one of the strong motivational factors in the process of learning mathematics (Lutfi & Dasari, 2023; Schunk & DiBenedetto, 2016; Schunk & Usher, 2019). Self-efficacy is one of the emotional factors that greatly influences an individual's achievement (Yohannes & Chen, 2024). High levels of self-efficacy can enhance achievement and well-being, leading individuals with high confidence to view difficult tasks as challenges rather than threats (Olawale & Hendricks, 2024).

In line with this, an individual's belief in their ability to cope with mathematical tasks can be described through the dimensions of self-efficacy. Bandura states that there are 3 dimensions of self-efficacy, namely magnitude, strength, generality (Zhu et al., 2019; Rahayu et al., 2017). Magnitude refers to the level of difficulty perceived by a person in completing a task (Rahayu et al., 2017). When individuals are faced with different levels of difficulty tasks, their self-efficacy will vary. They will tend to tackle tasks that match the level of ability they believe they have. Strength reflects the extent to which a person believes they can carry out a particular task, so this dimension is also related to individual enthusiasm and difficulty (Mukhibin & Himmah, 2020). Individuals who have strong self-efficacy tend not to give up easily and be persistent in overcoming obstacles, even when faced with obstacles. On the other hand, individuals with weak self-efficacy tend to be more susceptible to being affected by minor obstacles when they are undergoing tasks or challenges. Generality refers to the extent to which individuals are confident in their own abilities (Kasturi et al., 2021). This relates to how broadly individuals believe in their ability to complete various tasks and succeed in various situations. (Ananda & Wandini, 2022) stated that generality can indicate that individuals who are confident in their mathematics abilities tend to be more motivated to face challenges and strive to achieve success in learning mathematics.

Furthermore, mathematics learning does not only focus on mastering mathematical concepts and procedures, but also involves developing mathematical understanding that considers argumentation as an important aspect in it. Argumentation can be defined as statements used to support, justify, or refute an idea using reasonable premises (Jagadianti & Rosyidi, 2023). Mathematical argumentation plays a role in helping individuals come up with a variety of creative mathematical approaches and solutions. Toulmin in (Wohlrapp, 2014) classified several components of argumentation namely, claims, grounds, warrants, backings, qualifiers, and rebuttals to help understand how mathematical argumentation is constructed and evaluated. Claims are defined as statements or propositions to be proven or supported in an argument; Grounds are defined as information or evidence used to support a claim; Warrants are defined as logical connections between grounds and claims; Backings are additional information or evidence that support the validity of warrants; Qualifiers are defined as claim boundaries that indicate the extent to which the claim is relevant; Rebuttals are counter-arguments that contradict the claim (Arifin et al., 2023).

Teachers' self-efficacy and mathematical argumentation can directly influence the quality of mathematics instruction and the development of students' thinking. This is supported by several studies showing that teachers play a role in student success in the classroom (Óskarsdóttir et al., 2020; Özdemir, 2019; Taylor & P. Ringlaben, 2012). Teachers' self-efficacy and skills about mathematics will influence students' abilities in the substance of the material they teach (Yasin, 2022). In addition, the context of mathematics education at the tertiary level is the basis of further mathematical understanding as well as the foundation of knowledge to be imparted to students. Therefore, teachers' self-efficacy and skills about mathematics not only affect the quality of current instruction, but also form a solid foundation for students' further understanding of mathematics.

Previous research related to self-efficacy in the context of argumentation in the field of mathematics conducted by (Yıldız-Feyzioğlu & Kıran, 2022) showed the importance of self-efficacy in the context of argumentation which can also be applied in mathematical argumentation. In that

study, prospective teachers who have high self-efficacy in argumentation are able to guide students in developing mathematical argumentation skills. Another research related to self-efficacy and mathematical argumentation was conducted by (Kurniawan et al., 2023) which focused on investigating students' mathematical argumentation skills when proving mathematical statements based on their self-efficacy. The method used was qualitative with a case study design. The research by Ratu et al., (2024) indirectly also connects the mathematics argumentation with self-efficacy. The research uses a quantitative method with a quasi-experimental nonequivalent post-test control group design. Based on the three studies related to self-efficacy and mathematical argumentation, it appears that mathematical argumentation is an important skill in understanding, applying, and developing mathematical concepts. It is often related to the level of self-efficacy that an individual has. Therefore, further research is needed to explore the correlation between self-efficacy and mathematical argumentation. A better understanding of this relationship can provide deeper insights to improve the argumentation skills of pre-service teachers. Based on this description, researchers are interested in knowing the correlation between self-efficacy and mathematical argumentation in Mathematics Education students.

Method

This research uses a quantitative approach with a correlational method. This type of research seeks to explore whether there is a relationship between two or more variables. The data collection technique used a survey method by distributing questionnaires and math assignments to a number of respondents. A total of 41 Mathematics Education students at one of the state universities in Surabaya were selected as respondents using the random sampling method. Respondents consisted of active students of class 2022 and class 2020. This research was conducted in October 2023.

The instruments used were ten questionnaire questions related to self-efficacy and mathematics assignments on statistics material with a total of five numbers distributed in the form of Googleform. The self-efficacy questionnaire is in the form of a statement with the answer options strongly disagree, disagree, agree, and strongly agree. In addition, the mathematics task to reveal mathematical argumentation took the form of short questions with complex multiple answer options related to mathematical problems. The aspects studied were related to the three dimensions of self-efficacy by Bandura and the components of mathematical argumentation by Toulmin. The following indicators of mathematical argumentation components used for scoring are outlined in Table 1.

Table 1. Mathematical Argumentation Component Indicators

Content	Indicator
Claim (C)	Exressing an opinion.
Grounds (G)	Provide evidence or facts that support the claim.
Warrants (W)	Linking claims and grounds in the form of formulas/rules that apply that justify the claim.
Backings (B)	Provides support to warrants.
Qualifier (Q)	Indicates the ration type of power to be associated with a claim based on its relationship to grounds, warrants, and backings.
Rebuttals (R)	Stating exceptional circumtances that may make the claim no longer valid

In addition to mathematical argumentation indicators, this study also used self-efficacy indicators. Self-efficacy indicators related to the three dimensions by Bandura in (Schunk & Usher, 2019) are outlined in Table 2 below.

Table 2. Self-efficacy Indicators

Dimension	Indicator
Magnitude	Solving difficult problems
	Look for ways to solve the problem if something is hindering the goal
	Easy to focus and achieve the goals
Strength	Coping efficiently in case of unforeseen events
	Knowing how to deal with unexpected situations
	Be able to face task beyond ability
	Stay calm when faced the adversity
Generality	Find several solutions when faced the problem
	Thinking of solutions when in trouble
	Persist in difficult situations

Then, the rating scale used for the self-efficacy questionnaire is a Likert Scale. The Likert scale is used to measure the extent to which respondents agree or disagree with certain statements. 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. Self-efficacy Likert Scale

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

The data in this study were then analyzed using the percentage calculation of the results of the acquisition score of each question item. The following is the formula for calculating the percentage of data.

$$Index\% = \frac{\sum score}{\sum maximum\ score} \times 100\%$$

From the percentage results obtained, then the scores are interpreted based on Table 4 below.

Table 4. Score Interpretation Criteria

Criteria	Precentage
Very Low	0% - 25%
Low	26% - 50%
High	51% - 75%
Very High	76% - 100%

Meanwhile, the mathematical argumentation score will be calculated based on the correct or incorrect answers of students on each item. Each correct answer is worth 20 points, and each wrong answer is worth 0 points. The maximum score that can be obtained from the mathematical argumentation task is 100 points, with each item with the correct answer worth 20 points. The following is a description of the assessment criteria in Table 5.

Table 5. Mathematical Argumentation Assesment Criteria

Criteria	Score
Weak	0 – 29
Medium	30 – 69
Strong	70 – 100

After the self-efficacy score with mathematical argumentation is known, then the analysis will be carried out. The analysis technique uses product moment correlation or Pearson's correlation if the data is normally distributed, while if the data is not normally distributed, Spearman's correlation analysis will be used. The analysis was conducted to find the correlation between self-efficacy and mathematical argumentation of Mathematics Education students.

Result and Discussion

Normally Test

The method used in testing the normality of the data in this study, using the Shapiro-Wilk test to determine whether the data is normally distributed or not. This test depends on the sample size and is often used for small samples. The data criteria are normally distributed if it has a significance greater than $\alpha = 0.05$, then H_0 is rejected. The following description is H_0 : the data is normally distributed; H_1 : the data is not normally distributed. The results of the data normality test are presented in Table 6.

Table 6. Data Normality Test Results

	Saphiro-Wilk			Category
	Statistics	Df	Sig.	
Self-efficacy	0.8581	41	0.0001	H_0 is rejected
Mathematical Argumentation	0.8991	41	0.00155	

It is assumed that the data is not normally distributed because $sig. < \alpha$, so H_0 is rejected. In other words, the difference between the sample data and the normal distribution is statistically large enough to be considered significant.

Correlation Test

Based on the results of the normality test, it was found that the self-efficacy data with mathematical argumentation were not normally distributed. Thus, the data analysis used to determine the correlation between self-efficacy and mathematical argumentation is Spearman Correlation. The following hypothesis is used to test the correlation.

H_0 : there is no correlation between self-efficacy and mathematical argumentation of Mathematics Education students.

H_1 : there is a correlation between self-efficacy and mathematical argumentation of Mathematics Education students.

Interpretation of self-efficacy can be presented with very high, high, low, and very low criteria.

Data on the level of self-efficacy of Mathematics Education students are presented in Table 7 below.

Table 7. Frequency of Student Self-efficacy Score

Criteria	Precentage	Frequency
Very Low	0% - 25%	1
Low	26% - 50%	0
High	51% - 75%	19
Very High	75% - 100%	21
Total		41

The results from Table 7 show that out of a total of 41 students, the majority have self-efficacy in the very high category of 21 students. This shows that of the entire population assessed, most students have high confidence in their ability to deal with certain tasks or situations.

Meanwhile, the frequency of mathematical argumentation scores obtained by students is presented in Table 8 below.

Table 8. Frequency of Student Mathematical Argumentation Score

Criteria	Score	Frequency
Weak	0 – 29	21
Medium	30 – 69	18
Strong	70 – 100	2
Total		41

Table 8 shows that the majority of the students have relatively weak mathematical argumentation. This is based on the number of students classified as having weak mathematical argumentation is more than the number of students classified as having strong or moderate mathematical argumentation.

Based on the data in Table 7 and Table 8, the correlation between self-efficacy and mathematical argumentation of Mathematics Education students can be depicted in the scatter plot diagram shown in Figure 1 as follows.

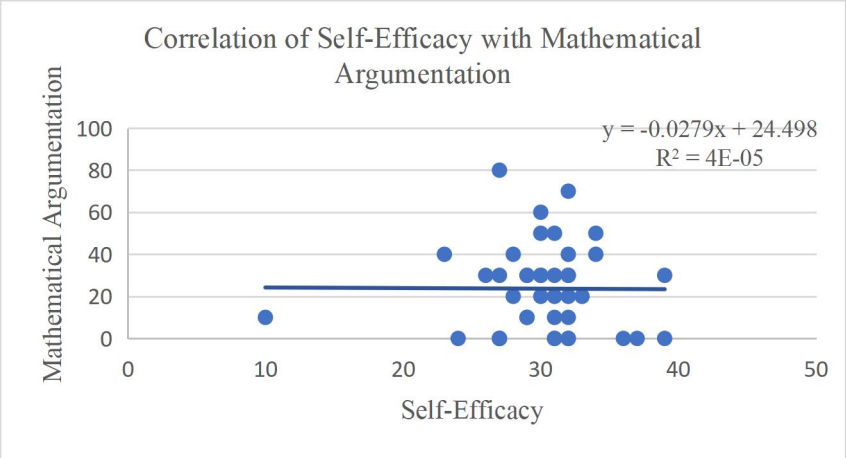

Figure 1. Scatter Plot Diagram of Correlation of Self-Efficacy with Mathematical Argumentation

Figure 1 indicates that there is no correlation between self-efficacy and mathematical

argumentation. The results are shown by $R^2 linier = 4E - 05$, this very small value means that the linear regression model cannot explain significant variation in the data. The low R^2 value indicates that the linear regression model cannot correctly predict the relationship between self-efficacy and students' mathematical argumentation. Since no significant correlation between self-efficacy and mathematical argumentation can be explained by the regression model, it is not possible to conclude that high or low levels of self-efficacy will directly affect students' level of mathematical argumentation. Figure 1 also shows that the two variables do not have a defined relationship or do not show a uniform pattern when one of the variables changes.

Table 9. Correlation Results of Self-efficacy with Mathematical Argumentation

	Mathematical Argumentation	
Self-Efficacy	*Spearman's Correlation*	0.02679
	Sig. (2-tailed)	0.86797
	N	41

Meanwhile, because the data were not normally distributed, the calculation used Spearman's Correlation. In Table 9, the Spearman's correlation coefficient value of 0.02679 indicates the level of relationship between self-efficacy and mathematical argumentation in the sample analyzed. The correlation coefficient is near zero, which indicates that there is no strong relationship between the two variables. A low value indicates that changes in one variable are not consistently associated with changes in the other variable.

Furthermore, the high significance (*Sig.*) value of 0.86797, indicates that the *Sig.* value is more than $\alpha = 0.05$. The high *Sig.* value indicates that the observed correlation coefficient may have occurred by chance or due to random variability in the data. When *Sig.* is greater than the preset α value (0.05), then there is not enough evidence to accept H_0.

Based on the data analysis, it was found that $Sig. > \alpha$ so H_0 can be accepted. This means that there is no correlation between self-efficacy and mathematical argumentation in Mathematics Education students. Based on the existing data, there is not sufficient evidence to reject the null hypothesis (H_0) which states that there is no relationship between the two variables. In other words, the results of this study indicate that the relationship that exists between self-efficacy and mathematical argumentation is not striking or consistent enough to be considered a real influence. When the results of the analysis show the absence of a significant correlation, this may indicate that self-efficacy and mathematical argumentation do not have a linear relationship in the sample studied (Bergqvist, 2024) . This means that changes in the level of self-efficacy do not cause measurable changes in mathematical argumentation abilities, or vice versa, in the context of the student group studied. This implies that the two variables may not influence each other directly in the context of this study. The absence of a significant relationship does not mean that there is no interaction at all between self-efficacy and mathematical argumentation. It is possible that the relationship between the two is not linear or is influenced by other variables not examined in this study. For example, factors such as teaching methods, prior knowledge, or external motivation may have a greater impact on mathematical argumentation skills than self-efficacy alone. Therefore, the complex dynamics influencing mathematical argumentation may involve the interaction of multiple factors that are not fully captured by this analysis. The finding that there is no relationship between self-efficacy and mathematical argumentation raises interesting questions regarding the complex dynamics behind the relationship. The results of this study have shown that the level of self-efficacy in mathematical ability is not always directly related to one's ability to construct strong arguments in a mathematical context. This challenges Bandura's assertion that self-efficacy influences one's ability to construct arguments (Schunk & DiBenedetto, 2016).

However, other studies such as that conducted by (Kurniawan et al., 2023) found a link between good self-efficacy and one's ability to prove mathematical statements with a solid argument structure. This finding indicates that individuals who have high self-efficacy in their mathematics abilities tend to be more effective in constructing mathematical arguments. Self-efficacy encourages them to put more effort into expressing arguments. Individuals with strong beliefs in their mathematical capabilities are more likely to invest significant cognitive resources into crafting arguments. This heightened engagement can be attributed to a combination of factors. Firstly, high self-efficacy fosters a growth mindset, encouraging individuals to view challenges as opportunities for learning rather than threats to their competence. This psychological resilience equips them to persist in the face of obstacles, a crucial attribute for constructing complex arguments. Secondly, individuals with high self-efficacy are more likely to adopt effective problem-solving strategies. They are more adept at breaking down complex problems into smaller, manageable steps, a skill essential for building logical and coherent arguments.

In addition, (Goldberg et al., 2019) also stated that in the context of mathematical argumentation, high self-efficacy can affect one's ability to construct strong and convincing arguments. Self-efficacy in one's mathematical abilities appears to be a catalyst for intellectual risk-taking. Individuals with high self-efficacy are more willing to explore unconventional ideas and to defend their reasoning with conviction. Mathematical breakthroughs often arise from novel approaches and perspectives. Individuals with high self-efficacy are more likely generate alternative solutions, and consider multiple possibilities. This openness to exploration can lead to the discovery of mathematical argumentation. Furthermore, self-efficacy empowers individuals to defend their unconventional ideas with conviction. Those with high self-belief are more likely to persist in their arguments, providing clear and compelling justifications for their reasoning. In this study, self-efficacy can be influential, as it can sway the critical thinking of an individual.

Both studies found that self-efficacy can have an impact on one's ability to prove mathematical statements and obtain conclusions that can be believed. Inconsistencies in these findings could be due to complex factors. One possible cause of this inconsistency is the variation in the methodology used. This difference in methodology can produce different results regarding the relationship between self-efficacy and mathematical argumentation (Nurlinda et al., 2024). Furthermore, both self-efficacy and mathematical argumentation can be measured at varying levels of detail. Mathematical argumentation requires the involvement of high-level cognitive processes, including logical reasoning, critical thinking, and problem-solving skills (Uzun, 2024) . These processes may require specific competencies that are not directly related to an individual's level of self-efficacy. Self-efficacy can also vary across mathematical tasks (Herset et al., 2024). This means that an individual's belief in their ability to perform a particular mathematical task can vary significantly depending on the nature of the task. For instance, a student might feel highly confident in their ability to solve algebraic equations but relatively less confident when faced with a geometry problem.

In addition, having a strong knowledge base of mathematical concepts and procedures may have a more significant impact than self-efficacy itself in determining the quality of argumentation. Similarly, the application of effective teaching methods that emphasize the importance of argumentation and reasoning can also contribute substantially to individuals' abilities, regardless of the extent to which they feel confident or empowered in the context of learning mathematics. There may also be other aspects of self-efficacy that are not fully understood in the context of mathematical argumentation. For example, how self-efficacy specifically affects strategy selection in constructing mathematical arguments or how it affects perseverance in the face of mathematical difficulties. Further research investigating these aspects may provide deeper insights into the relationship between self-efficacy in mathematics and argumentation skills in the domain.

Conclusion

Based on the results and discussion, it can be concluded that there is no correlation between self-efficacy and mathematical argumentation in Mathematics Education students. Although they have very strong self-efficacy, it is not enough to guarantee that their mathematical argumentation is strong. This finding contradicts the view that self-efficacy can directly influence one's ability to construct strong mathematical arguments. The implication is that it is important to consider other factors that may contribute to the development of mathematical argumentation skills. Meanwhile, this study highlights the need for further research to delve deeper into this complex relationship between self-efficacy and mathematical argumentation skills. References to previous studies on self-efficacy and mathematical argumentation, as well as theories related to motivation and leadership in educational contexts, provide an important basis for future research that can shed further light on the factors that influence students' abilities in mathematical domains. In this case, other factors beyond self-efficacy may have more influence on students' mathematical argumentation. Thus, to improve mathematical argumentation can be done by reviewing other factors besides self-efficacy.

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