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The impact of mathematical disposition and self-efficacy beliefs on secondary school students' mathematical literacy

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Abstract

The mathematical literacy skills of Indonesian students, as reflected in the PISA results, continue to be a concern because of their poor performance. Students with high mathematical disposition and high self-efficacy are often more proficient in mathematical literacy. This study aimed to examine how mathematical disposition and self-efficacy affect students' mathematical literacy skills. This study employed a quantitative approach with a nonexperimental design and adopted a causal associative methodology. Data collection involved administering mathematical disposition and self-efficacy questionnaires, along with a mathematical literacy test, to 56 junior high school students. The analysis was performed using structural equation modeling-partial least squares (SEM-PLS) in the JASP 0.18.3.0 application. The results showed that mathematical disposition significantly enhances both self-efficacy and mathematical literacy skills. Conversely, while self-efficacy positively influenced mathematical literacy skills, the effect was not statistically significant.

Keywords: mathematical disposition; mathematical literacy; self-efficacy

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Introduction

Mathematics, as the basis for technological advancement, plays an important role in education. The phenomena existing in the surrounding environment can be interpreted as mathematical problems and solved using mathematics. NCTM has set standards for mathematical skills, which consist of problem-solving, reasoning and proof, connection, communication, and representation (NCTM, 2000). In Indonesia, mathematics learning in an independent curriculum aims to develop students' understanding of concepts, reasoning, problem-solving, communication, mathematical connections, and appreciation of the benefits of mathematics in everyday life (Kemendikbudristek 2022). Moreover, the assessment in the Merdeka curriculum aims to measure mathematical and reading literacy (Novita et al., 2021). Furthermore, the learning objectives of mathematics that have been set are related to mathematical literacy, and students' mathematical literacy skills can increase as they achieve the mathematics learning objectives.

Mathematical literacy refers to the capacity to formulate, apply, and interpret mathematical concepts to solve problems across various real-life contexts (OECD, 2023a; Ojose, 2011). Globally assessed through the Programme for International Student Assessment (PISA), which also evaluates reading and science literacy, mathematical literacy serves as a critical indicator of educational achievement (Yalçın et al., 2012). Indonesia has consistently ranked among the bottom 10 countries in mathematics literacy since 2000, failing to achieve the minimum score of 500 (Nugrahanto & Zuchdi, 2019; OECD, 2023a), with a score sequence of 375, 386, 379, and 366 (OECD, 2014, 2016, 2019, 2023b). These scores indicate that Indonesia's mathematical literacy performance remains below the global standards.

Based on the low PISA results, Indonesian students' mathematical literacy skills are limited to Level 1, with only 0.6% of students able to solve problems at Level 5 and above (OECD, 2016). However, solving mathematical literacy problems at Level 1 only requires the use of general methods according to clear information in the problem (Sutrisno & Adirakasiwi, 2019). Furthermore, the problems given by teachers at school are usually routine problems whose solutions can be found only by applying the steps that have been taught, which causes students to have negative prejudices and consider math literacy problems very difficult, and students are easily discouraged (Hapsari, 2019).

Moreover, attitudes toward mathematics affect students' mathematical literacy (Shaw & Shaw, 1997). Low levels of confidence can hinder the enhancement of students' mathematical literacy skills (Parsons et al., 2009). Many people feel anxious and afraid of math and are unable to understand mathematical concepts (Henderson et al., 2020; Kunwar 2021a). Students tend to have a negative perception of math (Hoyles, 1982). Thus, a person's discomfort in dealing with everyday mathematical situations shows that attitudes can affect their mathematical literacy.

The importance of the affective domain is reflected in the five general objectives described by NCTM (1988). An aspect relevant to the attitude toward mathematics is a mathematical disposition (Gabriel et al., 2018), which aligns with Kilpatrick et al. (2001) delineation of five standards for mathematical proficiency: conceptual understanding, procedural skills, strategic problem-solving skill, adaptive reasoning, and productive disposition. Mathematical disposition encompasses students' positive attitudes towards learning and solving mathematical problems (Akmal et al., 2022) and comprises components such as self-confidence, perseverance, curiosity, and perception of mathematics (Kurniati et al., 2017; Mayratih et al., 2019). Self-confidence plays a crucial role in students' approach to mathematical challenges. Insufficient confidence may lead students to adopt dishonest practices in pursuit of the desired outcomes.

According to NCTM (1988), assessing mathematical dispositions involves several key aspects: (1) students' confidence in using mathematics for problem-solving, communication, and reasoning; (2) students' flexibility to explore mathematical concepts and employ various strategies to solve problems; (3) students' enthusiasm and diligence in handling mathematical tasks; (4) interest, curiosity, and competence in mathematics; (5) reflection on the results of every thought and action; (6) understanding of the relevance of mathematics in other fields and everyday life; and (7) an attitude of appreciating the role of mathematics in culture (NCTM, 1988).

Self-efficacy is another aspect needed to develop students' mathematical literacy skills. Self-efficacy refers to an individual's confidence in succeeding in a challenge (Alqusyairi et al. 2021). Many findings regarding self-efficacy are closely related to mathematical disposition and students' academic achievement, especially in mathematics (Marks et al., 2001; Richardson et al., 2012; Schulz, 2005). Nicolaidou and Philippou (2003) stated that self-efficacy affects academic achievement and controls the prediction of success in mathematics tasks. Moreover, Alqusyairi et al. (2021) confirmed a relationship between mathematical literacy and self-efficacy in improving students' ability to solve mathematical problems.

Three main dimensions are the basis for measuring self-efficacy: magnitude, strength, and generality. The magnitude dimension is related to an individual's belief in their ability to solve problems, as seen from the difficulty level of the problem. With self-efficacy, people can solve problems or tasks according to their limits. The strength dimension relates to how strongly a person believes in their skills to face challenges and be able to survive in any situation. Individuals with high self-efficacy tend to remain persistent and resistant to obstacles. Additionally, the generality dimension relates to an individual's belief in applying their abilities and knowledge widely to various tasks (Bandura, 1997). Thus, it can be reinforced that self-efficacy has an important role in supporting a person when solving math problems. Consequently, self-efficacy is connected to mathematical literacy, which requires students to solve everyday problems by formulating, applying, and interpreting mathematics in various contexts.

Students with high self-efficacy can solve difficult mathematical problems (Yulianah et al., 2022). This finding was reinforced by Nisa and Arliani (2023), who implied that the higher a person's mathematical self-efficacy, the higher their mathematical literacy tends to increase. However, some findings show different results, stating that mathematical literacy has a moderate relationship with self-efficacy (Ozgen, 2013), indicating that the relationship between self-efficacy and mathematical literacy is not as strong. Ding (2016) stated that self-efficacy was not the biggest factor in improving mathematical literacy among students in Sweden; instead, other factors such as socioeconomic status were identified as the strongest predictors of mathematical literacy. Rahmanuri et al. (2023) concluded that some of the dominant factors that influence mathematical literacy are verbal skills and mathematical disposition.

Enhancing students' mathematical literacy skills is an important effort in various sectors. In the context of mathematics education, fostering students' mathematical literacy skills is one of the primary objectives as it aids in finding solutions to problems that exist in everyday life (Nurlaili et al., 2022). This is inseparable from the various related factors. Mathematical disposition, literacy, and self-efficacy are interrelated aspects of mathematics education. In this context, the initial assumption was that mathematical disposition influences self-efficacy, affects mathematical literacy skills, and impacts mathematical literacy skills. Although numerous studies have explored the impact of mathematical disposition on mathematical literacy and the influence of self-efficacy on mathematical literacy, previous research has typically focused on only one of these factors. Therefore, this study aimed to investigate the influence of mathematical disposition and self-efficacy on students' mathematical literacy.

Methods

This research utilized a quantitative approach with a causal associative design. The study was non-experimental, as the researcher did not administer any treatment to the sample. According to Sandjojo (2011), path analysis research design would determine the relationship and influence between latent variables, which was an extension of multiple regression analysis. This study aimed to analyze whether (1) there is an effect of mathematical disposition (MD) on mathematical literacy skills (MLS), (2) there is an effect of self-efficacy (SE) on mathematical literacy skills (MLS), and analyze whether (3) there is an effect of mathematical disposition (MD) on student self-efficacy (SE). The relationship among variables is represented by the following structural model.

1. SE = MD + e1
2. MLS = MD + SE + e2

The model components comprise latent variables (MD, SE, MLS) and the relationships between these variables. The latent variable MD (Mathematical Disposition) is represented by seven indicators (DM1–DM7), the latent variable SE (Self-Efficacy) is represented by three indicators (SE1–SE3), and the data of latent variable MLS (Mathematical Literacy Skills) was obtained from students' test scores. The representing indicators are in the following measurement model.

1. $\mathrm{MD}_1 = \lambda_{MD1}MD$, $\mathrm{MD}_2 = \lambda_{MD2}MD$, $\mathrm{MD}_3 = \lambda_{MD3}MD$, $\mathrm{MD}_4 = \lambda_{MD4}MD$, $\mathrm{MD}_5 = \lambda_{MD5}MD$, $\mathrm{MD}_6 = \lambda_{MD6}MD$, $\mathrm{MD}_7 = \lambda_{MD7}MD$
2. $\mathrm{SE}_1 = \lambda_{SE1}SE$, $SE_2 = \lambda_{SE2}SE$, $\mathrm{SE}_3 = \lambda_{SE3}SE$.

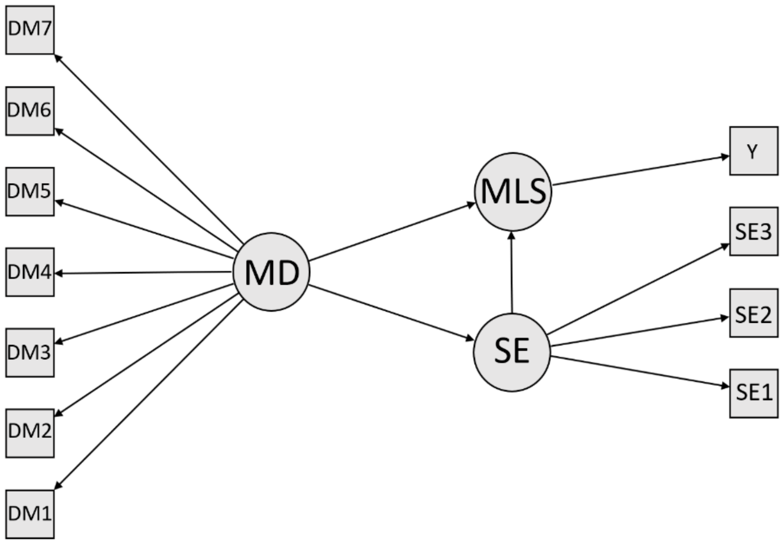

Figure 1. Structural model

Data for MD was collected through a questionnaire with 7 indicators, and data for SE was collected through a questionnaire with 3 indicators. Both the MD and SE questionnaires utilized a four-point Likert scale, with options ranging from "strongly disagree" (1), "disagree" (2), "agree" (3), to "strongly agree" (4). Meanwhile, the mathematical literacy skill test (MLS) consists of 2 questions, which are equivalent to PISA standards and focus on the topic of ratios. The study population consisted of all students at SMP LABSCHOOL UPI, using a random sampling technique, resulting in 56 seventh-grade students being selected as the research sample.

The inferential statistical analysis in this study employed Structural Equation Modeling - Partial Least Squares (SEM-PLS). The SEM-PLS method was tested using the JASP 0.18.3.0 software. The main advantage of the SEM-PLS method is its ability to eliminate assumptions and biases, offering reliable implications and accurate prediction capabilities (Ghozali, 2015). Additionally, SEM-PLS does not require the data to follow a normal distribution or need a large sample size, thus it can bypass the assumptions inherent in parametric statistics.

Results

This study aimed to test the structural model as shown on figure 1. Hypothesis testing used bootstrapping with 1000 subsamples. The results of PLS-SEM analysis indicated that MD had a positive and significant effect on MLS ($p < 0.05$), and MD had a positive and significant effect on SE ($p < 0.05$). On the other hand, SE had a positive but insignificant effect on MLS, with a p-value of 0.391. Below is the figure 2 presenting the graphical output of PLS-SEM results.

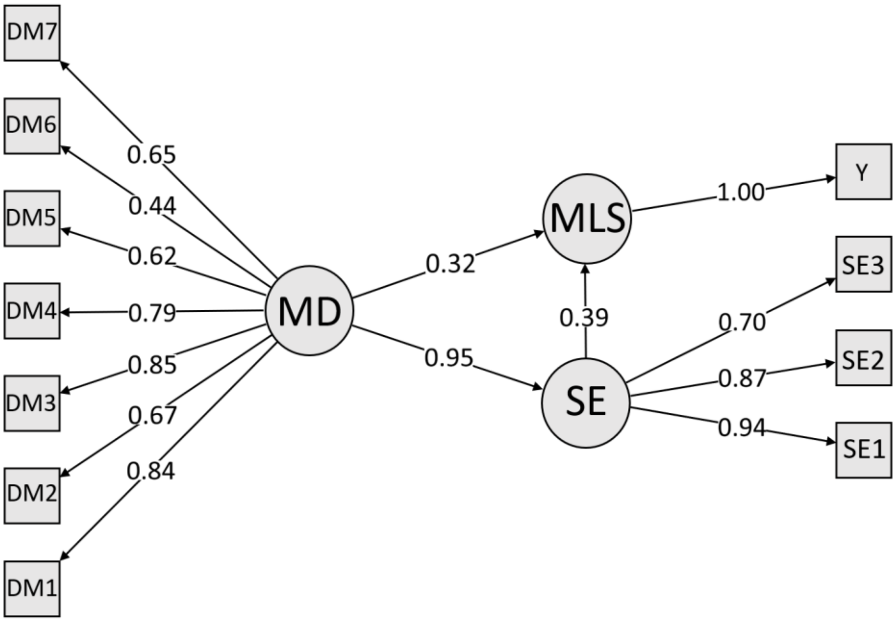

Figure 2. Graphical output

Based on Figure 2, the indicators that best measure or contribute to Mathematical Disposition are DM1 and DM3, as they exhibit the highest factor loadings. Conversely, DM6 has the lowest factor loading, indicating that it is less representative of the latent variable compared to the other indicators. In contrast, all self-efficacy indicators (SE1–SE3) demonstrate sufficient factor loadings, suggesting they are valid measures of the Self-Efficacy variable.

Based on path coefficients presented in Figure 2, Mathematical Disposition has a weak positive relationship with Mathematical Literacy Skills (0.32), and Self-Efficacy similarly shows a weak positive relationship with Mathematical Literacy Skills (0.39). However, Mathematical Disposition exhibits a strong positive relationship with Self-Efficacy (0.95)

Hypothesis Testing

Table 1. Total effect

Outcome	Predictor	Estimate	Std. Error	z-value	p	95% CL	
						Lower	Upper
SE	MD	0.951	0.034	27.773	< 0.001	0.868	0.995
MLS	MD	0.687	0.0.60	11.359	< 0.001	0.563	0.791
	SE	0.390	1.414	0.276	0.391	-2.497	2.484

Table 1 illustrates the comprehensive effect (both direct and indirect) of one variable on another within the structural model. As indicated in Table 1, MD exerted a strong positive influence on SE (estimate = 0.951), accompanied by a relatively small standard error of 0.034. This effect was also statistically significant, as evidenced by a p-value of <0.001. Additionally, MD had a positive effect on MLS (estimate = 0.687), with a similarly small standard error, and this effect was also statistically significant. In contrast, the effect of SE on MLS was positive (estimate = 0.390) but not statistically significant (p-value = 0.391).

Table 2. R-squared

Outcome	R^2	Adjusted R^2
SE	0.922	0.921
MLS	0.477	0.457

The appropriateness of the model in this study was assessed by using the R-square value for each endogenous variable. The endogenous variables in this research were MLS and SE. According to the R-squared table presented, the MD variable explained 92.2% of the variance in SE, with the remaining 7.8% attributed to other factors. Furthermore, MD and SE collectively accounted for 47.7% of the variance in MLS, with the remaining 52.3% attributable to other variables.

Table 3. Regression coefficients

Outcome	Predictor	Estimate	f^2	Std. Error	z-value	p	95% CL	
							Lower	Upper
SE	MD	0.951	11.826	0.034	27.773	< 0.001	0.868	0.995
MLS	MD	0.317	0.010	1.413	0.224	0.411	-1.805	3.189
	SE	0.390	0.028	1.414	0.276	0.391	-2.497	2.484

Table 3 shows that the estimated value or the size of the regression coefficient between variables was almost the same as the estimated value in the total effect table. However, what made the difference was the regression coefficient of MD on MLS, which was 0.317. It indicates the indirect effect of MD on MLS through SE as a mediator. Additionally, the indirect effect can be determined as follows:

$$\text{MD} -> \text{SE} -> \text{MLS} = 0.951 \times 0.390 = 0.371$$

Based on the regression coefficients presented in Table 3, the following structural equations are derived:

$$\text{SE} = 0.951\,\text{MD} + e1$$
$$\text{MLS} = 0.317\,\text{MD} + 0.390\,\text{SE} + e2$$

The SE error value (e1) can be derived from the R^2 value for SE (0.922), while the MLS error value (e2) can be derived from the R2 value for MLS (0.477) using the following formula:

$$e1 = \sqrt{1 - R^2} = \sqrt{1 - 0.922} = \sqrt{0.078} = 0.279$$
$$e2 = \sqrt{1 - R^2} = \sqrt{1 - 0.477} = \sqrt{0.523} = 0.723$$

Thus, the structural equation becomes:

$$\text{SE} = 0.951\,\text{MD} + 0.279$$
$$\text{MLS} = 0.317\,\text{MD} + 0.390\,\text{SE} + 0.723$$

According to the structural equation above, a 1-unit increase in MD resulted in a 0.317 increase in MLS, and a 1-unit increase in SE resulted in a 0.390 increase in MLS. Furthermore, the MLS error value of 0.723 indicated unexplained variance in MLS, attributed to factors not included in the model involving MD and SE.

Table 4. Factor loadings

Latent	Indictor	Estimate	Std. Error	z-value	p	95% CL	
						Lower	Upper
MD	MD1	0.841	0.065	12.910	< 0.001	0.700	0.955
	MD2	0.665	0.112	5.950	< 0.001	0.419	0.854
	MD3	0.845	0.051	16.453	< 0.001	0.732	0.931
	MD4	0.790	0.060	13.223	< 0.001	0.650	0.887
	MD5	0.624	0.095	6.560	< 0.001	0.429	0.799
	MD6	0.435	0.145	3.012	0.001	0.121	0.700
	MD7	0.647	0.111	5.851	< 0.001	0.383	0.825
SE	SE1	0.941	0.037	25.663	< 0.001	0.856	0.995
	SE2	0.865	0.048	17.958	< 0.001	0.751	0.937
	SE3	0.699	0.100	6.967	< 0.001	0.470	0.852
MLS	Y	1.000	0.000	∞	< 0.001	1.000	1.000

Table 4 shows the validity of convergence on each indicator through SEM-PLS analysis called *factor loadings. The* value of *factor loadings* above 0.6 indicates that the indicators meet the validity requirements (Hair et al., 2012), thus meeting the validity standards for measuring MD, SE, and MLS variables. According to the table, all indicators have met the validity requirements, except MD6 (6th mathematical disposition indicator), namely students' understanding of the usefulness of mathematics in other disciplines and everyday life. Indicator MD6 does not meet the requirements because its *factor loading* value is 0.435 <0.6. Because this research uses reflective model, therefore the MD6 indicator can be removed from the measurement model as follows.

1. $\mathrm{MD}_1 = 0.841MD,\quad \mathrm{MD}_2 = 0.665MD,\quad \mathrm{MD}_3 = 0.845MD,\quad \mathrm{MD}_4 = 0.790MD,\quad \mathrm{MD}_5 = 0.624MD,\quad \mathrm{MD}_7 = 0.647MD$
2. $\mathrm{SE}_1 = 0.941SE,\ SE_2 = 0.865SE,\ \mathrm{SE}_3 = 0.699SE.$

Table 5. Realibility masures

Latent	Cronbach's α	Jöreskog's ρ	Dijkstra-Henseler's ρ
MD	0.874	0.875	0.891
SE	0.879	0.881	0.896
MLS	NaN	1.000	1.000

Table 5 indicates high reliability with Cronbach's α > 0.7 for each variable, complemented by high Dijkstra-Henseler's p-values. These results confirm the reliability of the variables in the study.

Discussion

This study identified the relationships among the variables of mathematical disposition, self-efficacy, and mathematical literacy skills. According to the total effect results, mathematical disposition positively influenced mathematical literacy skills. Thus, students demonstrating strong mathematical dispositions also exhibited proficient mathematical literacy skills. This discovery aligns with relevant statements that students with high mathematical dispositions have higher mathematical literacy skills, adeptly formulating problems, employing suitable strategies, and articulating reasoning effectively (Hendroanto et al., 2018; Nurhayati et al., 2024; Rahmawati et al., 2021). However, in the direct effect result, mathematical disposition did not significantly influence mathematical literacy skills. This indicates that the influence of mathematical disposition on mathematical literacy skills occurs through more complex pathways or other variables that are not measured in this model. Therefore, further research is needed to explore potential mediating or moderating variables that could explain this relationship more clearly.

Mathematical disposition has a positive and significant effect on students' self-efficacy. This confirms that students who possess strong mathematical dispositions tend to demonstrate high self-efficacy in handling mathematical tasks. On the other hand, the findings of Izzati and Widyastuti (2021) argued that self-efficacy influences students' mathematical disposition. Therefore, this study suggests a reciprocal relationship between mathematical disposition and self-efficacy (Reciprocal Causality).

The results of this study suggest that self-efficacy positively influences mathematical literacy skills, although the effect is not statistically significant. Despite students with high self-efficacy also demonstrating high mathematical literacy skills, the lack of statistical significance in this relationship may be attributed to the study's small sample size, limiting generalizability. As in Cheema (2018) research using a large sample obtained the result that self-efficacy has a significant effect on students' mathematical literacy skills. Likewise, Gabriel et al. (2018) who used a large sample stated that self-efficacy made the greatest contribution in the model being evaluated. High self-efficacy contributes to students' mathematical literacy test results (Tariq et al., 2013). On the other hand, Ding (2016) argued that in Sweden, socioeconomic status, rather than self-efficacy, plays a more significant role in enhancing students' mathematical literacy skills.

Nevertheless, while the direct influence of self-efficacy on mathematical literacy skills may not be significant, self-efficacy serves as a mediator in the relationship between mathematical disposition and mathematical literacy skills. This suggests that the indirect effect of mathematical disposition on mathematical literacy skills operates through self-efficacy as a mediator. Essentially, a strong mathematical disposition enhances students' self-efficacy, which in turn supports the development of their mathematical literacy skills.

Although self-efficacy did not have a significant direct effect on mathematical literacy, the analysis showed that self-efficacy has the potential to strengthen the effect of mathematical disposition on literacy. This opens up opportunities to utilize self-efficacy as a focal point in educational interventions, for example by implementing discovery learning in order to increase students' confidence to tackle complex mathematical tasks, thus supporting the overall improvement of mathematical literacy (Martalyna et al., 2018).

The results also indicated that one of the mathematical disposition indicators, namely "students' understanding of the usefulness of mathematics in other disciplines and everyday life" (MD6) was invalid. This indicator is also not included in the indicators of mathematical disposition in some previous studies. The indicators used in these studies are self-confidence, strength, desire to know, and perception of mathematics (Kurniati et al., 2017; Mayratih et al., 2019). Therefore, these indicators need to be reconsidered in future research.

Multiple factors influence students' mathematical literacy skills. The findings indicate that 47.7% of the variance in these skills can be explained by mathematical disposition and self-efficacy. The remaining 52.3% represents variance due to other factors not accounted for by these variables. Despite the significant influence of mathematical disposition and self-efficacy on mathematical literacy skills, other factors also play important roles in enhancing students' mathematical literacy abilities. These factors include mathematics self-concept (Ding, 2016; Gabriel et al., 2020; Sezgin, 2017), motivation level (Aksu & Güzeller, 2016; İnal & Turabik, 2017; Sezgin, 2017; Üredi & Üredi, 2005), social and economic status (Ding, 2016; Sezgin, 2017), and math anxiety (Gabriel et al., 2018; Harefa et al., 2023).

Conclusion

Mathematical disposition had a positive and significant influence on students' mathematical literacy skills and self-efficacy. The better students' mathematical disposition, the better their mathematical literacy skills, and their self-efficacy in facing mathematical tasks will also increase. Meanwhile, self-efficacy had a positive but insignificant effect on mathematical literacy skills. Nevertheless, high self-efficacy supports the improvement of mathematical literacy, where self-efficacy acts as a mediator in the relationship between mathematical disposition and mathematical literacy. In addition, this study identified that one of the mathematical disposition indicators used needs to be reconsidered in future research. Overall, the findings shed light on the importance of developing students' mathematical disposition and self-efficacy to improve their mathematical literacy skills.

These findings highlight the importance of engaging students in activities that foster a positive mindset toward mathematics and its practical applications, as mathematical disposition significantly impacts students' mathematical literacy skills. The substantial influence of mathematical disposition on self-efficacy implies that schools should prioritize interventions to develop students' mathematical disposition. Strategies such as encouraging curiosity, perseverance, and responsibility in learning mathematics, and recognizing students' achievements in mathematics, can help build their confidence in their mathematical abilities. This study has limitations regarding the sample size used to analyze the relationships between variables. A larger sample would greatly enhance the robustness of quantitative research. Future studies employing larger samples could evaluate the structural model proposed in this study using Structural Equation Modeling (SEM).

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

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Author Contributions

Hanifah Nurhayati: Conceptualization, writing - original draft, editing, data statistically analyzing, investigation, and visualization; **Aan Hasanah:** Review, and formal analysis; **Dadan Dasari:** Review, and Metodology.

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