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The Effect of Using Geogebra, Self-Efficacy, Hard Work Character, and Critical Thinking Ability on Mathematics Learning Achievement

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Abstract:
Mathematical skills are essential in academic contexts, everyday life, and various professional fields. This study is motivated by the low achievement of Indonesian students' mathematics skills in the PISA survey and the importance of integrating technology and psychological factors in 21st-century mathematics learning. This study analyzes the direct and indirect effects of using GeoGebra, self-efficacy, complex work character, and critical thinking ability on students' mathematics learning achievement. This study uses a quantitative approach with a correlational research design and involves a sample of 156 grade XI students at a high school in Boyolali. Data collection was carried out through questionnaires and tests, which were tested for validity and reliability, and data analysis was carried out by path analysis using SPSS. The results showed that the use of GeoGebra and self-efficacy had a significant direct effect on the character of hard work. However, the four variables had no significant direct effect on mathematics learning achievement. The indirect effect of self-efficacy on learning achievement through complex work character was significant, while the other indirect paths were insignificant. This study concludes that complex work character is an important mediator that connects self-efficacy with mathematics learning achievement. This study recommends strengthening self-efficacy and utilising learning technologies such as GeoGebra and appropriate pedagogical strategies to build positive learning dispositions and improve mathematics learning outcomes.

Abstrak:
Kemampuan matematika sangat penting dalam konteks akademis, kehidupan sehari-hari, dan berbagai bidang profesi. Penelitian ini dilatarbelakangi oleh rendahnya pencapaian kemampuan matematika siswa Indonesia dalam survei PISA dan pentingnya mengintegrasikan teknologi dan faktor psikologis dalam pembelajaran matematika abad ke-21. Penelitian ini mengevaluasi pengaruh baik secara langsung maupun tidak langsung dari penggunaan GeoGebra, self-efficacy, karakter kerja keras, dan kemampuan berpikir kritis terhadap prestasi belajar matematika siswa. Pendekatan yang digunakan adalah kuantitatif dengan desain penelitian eksplanatori, melibatkan 156 siswa kelas XI dari SMA Negeri 1 Boyolali sebagai sampel penelitian. Pengumpulan data dilakukan melalui kuesioner dan tes yang telah diuji validitas dan reliabilitasnya, dan analisis data dilakukan dengan analisis jalur menggunakan SPSS.

Hasil penelitian menunjukkan bahwa penggunaan GeoGebra dan efikasi diri berpengaruh langsung secara signifikan terhadap karakter kerja keras. Namun, keempat variabel tersebut tidak memiliki pengaruh langsung yang signifikan terhadap prestasi belajar matematika. Pengaruh tidak langsung efikasi diri terhadap prestasi belajar melalui karakter kerja kompleks adalah signifikan, sedangkan pengaruh tidak langsung lainnya tidak signifikan. Penelitian ini menyimpulkan bahwa karakter kerja merupakan mediator penting yang menghubungkan efikasi diri dengan prestasi belajar matematika. Penelitian ini menyimpulkan bahwa karakter kerja merupakan mediator penting yang menghubungkan efikasi diri dengan prestasi belajar matematika. Penelitian ini merekomendasikan untuk memperkuat efikasi diri dan memanfaatkan teknologi pembelajaran seperti GeoGebra dan strategi pedagogis yang tepat untuk membangun disposisi belajar yang positif dan meningkatkan hasil belajar matematika.

Keywords:
GeoGebra, Self-Efficacy, Hard Work, Critical Thinking, Math Learning Achievement

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INTRODUCTION

Mathematics is fundamental in developing logical, analytical, and systematic thinking skills. Mathematical skills are essential in academic contexts, everyday life, and various professional fields (Shen, Chen, Zhang, Diao, Liu, & Zhou, 2025). According to NCTM (2020), effective mathematics learning should develop students' conceptual understanding and problem-solving skills to apply mathematical knowledge in various situations. In addition, the NRC (2001) outlines five strands of mathematical proficiency conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition which further align with the expected outcomes, emphasizing a balanced mastery of mathematical skills, reasoning, and application in real-world contexts, Filiz (2024) emphasised that strong mathematical literacy is needed to face the challenges of the digital and data era and to prevent falling behind in global competition.

However, the reality shows that mathematics learning in Indonesia still faces serious challenges. The Program for International Student Assessment

(PISA) survey results in 2022 showed that the average score of Indonesian students' mathematics skills only reached 366, far below the average of OECD countries at 472 (OECD, 2022). This limited performance indicates that numerous students have difficulty grasping and applying fundamental mathematical concepts in real-world contexts. Contributing factors include teaching methods that are still conventional and less varied, the lack of technology in learning, and students' low motivation and confidence in their mathematical abilities (Kusmaryono & Kusumaningsih, 2023). These conditions indicate that improving the quality of mathematics learning requires a more innovative, contextual, and holistic approach to foster deep understanding, positive attitudes towards mathematics, and higher-order thinking skills relevant to the demands of the 21st century.

A key factor that affects success in learning mathematics is the trait of hard work or grit, characterized by persistence and passion in pursuing long-term goals, even in the face of challenges and setbacks. In education, hard work can be interpreted as a continuous, dedicated, and consistent effort in achieving optimal learning outcomes, without giving up easily despite challenges (Ogden, Darrah, & Leppma 2023). According to Alhadabi and Karpinski (2020); Duckworth, Peterson, Matthews, and Kelly (2007), grit is a combination of passion and perseverance to achieve goals, which has been shown to contribute significantly to critical thinking and academic achievement, including mathematics. Meanwhile, Al-Mutawah and Fateel (2018) included hard work in the strength of character category, which is closely related to self-control, responsibility, and the drive to complete tasks to completion. Students with a strong sense of grit or a hardworking character are generally more capable of enduring challenges, maintaining consistency in their studies, and remaining committed to long-term educational objectives. The development of this character can be done through learning that is challenging, meaningful, and provides space for students to experience learning processes that encourage perseverance, mental endurance, and a sense of responsibility for their success.

In addition to character, critical thinking is essential to learning mathematics. Critical thinking allows students to process information through logical analysis, careful evaluation, and systematic synthesis (Amin, Corebima, Zubaidah, & Mahanal, 2020). Critical thinking is generally defined as making appropriate and reasoned judgments based on evidence and logic. According to Facione (2011) and Hattori (2025), critical thinking is a directed and reflective thought process used to make rational decisions. Thorndahl and Stentoft (2020) added that critical thinking includes the ability to think logically and rationally about what to believe or do, and is based on accountable criteria. Meanwhile, Applebaum (2025) explains that ritical thinking is a purposeful and engaged mental process that involves disciplined reasoning to comprehend and assess information impartially so that it can improve students' academic achievement. In mathematics, this ability is essential in solving complex problems, critical thinking skills, constructing valid mathematical arguments, and forming generalisations from concepts learned (Sachdeva & Eggen, 2021). Therefore, mathematics instruction should be structured to foster the development of students' critical thinking skills through challenging tasks, reflective discussions, and contextual problem-solving that promotes deep analysis and sound decision-making.

To support the achievement of these goals, using technology such as GeoGebra can be an effective strategic solution. GeoGebra is a dynamic math software based on information technology that integrates geometry, algebra, statistics, and calculus in one interactive platform easily accessible and used by teachers and students (Zakaria, Carol, Hanid, Adnan, Raimi, & Azman, 2024). According to Hohenwarter and Preiner (2007); Latifi, Hattaf, and Achtaich (2021), GeoGebra is designed to connect visual and symbolic representations simultaneously, allowing users to build a more intuitive and exploratory understanding of mathematical concepts and not only facilitates deep understanding, but can also increase students' motivation and hard work in learning mathematics. It enriches the visual learning experience and encourages active student engagement and critical thinking through direct manipulation of mathematical objects. A meta-analysis study by Zhang, Wang, Jia, and Zhang (2023) showed that using GeoGebra significantly positively affects students' math skills. In addition to improving concept understanding, GeoGebra can motivate students and facilitate more collaborative and contextualised learning (Yohannes & Chen, 2023). Thus, this technology supports conceptual mastery of mathematical materials and strengthens the development of students' critical thinking skills through active, reflective, and meaningful learning experiences.

Psychological aspects like self-efficacy are also essential in mathematics learning. Self-efficacy refers to a person's confidence in their capability to accomplish tasks or reach particular objectives (Zakariya, 2022). Albert Bandura (1997), who introduced this concept, explained that self-efficacy is a person's belief in their ability to organise and carry out the actions needed to achieve desired results. These beliefs affect how individuals critical thinking, feel, and act in the face of challenges. Research by Yang, Maeda, and Gentry (2024) showed that self-efficacy significantly correlates with hardwork and students' mathematics achievement. Learners with strong self-efficacy are generally more driven, resilient, and better equipped to handle challenges throughout the learning journey (Street, Malmberg, & Stylianides, 2022). Therefore, teachers need to create a learning environment that supports the development of student confidence through reinforcing positive learning experiences and providing constructive feedback.

Previous research relevant to this study has been conducted. Some of them are research conducted by Saputro, Atun, Wilujeng, Ariyanto, and Arifin (2020) on the relationship between self-efficacy and critical thinking skills. Research by Setyawan, Anas, Nasir, and Fadly (2024) regarding the use of GeoGebra on critical thinking skills, then research by Pang and Veloo (2024) examines the effect of self-efficacy on learning achievement, further research by Kaya and Karakoc (2022) discusses the relationship of hard work to learning achievement, besides research by Setiana, Purwoko, and Sugiman (2021) regarding the relationship of critical thinking to student learning achievement, and research by Zetriuslita, Nofriyandi, and Istikomah (2020) related to the role of using GeoGebra and self-efficacy on student learning achievement. However, no research explicitly examines the simultaneous relationship between using GeoGebra, self-efficacy, hard work, and critical thinking on students' mathematics learning achievement. In addition, the approaches used in previous studies are generally limited to simple or multiple regression analysis. In contrast, this study uses path analysis to describe the direct and indirect relationships between variables in more depth. Therefore, further studies are needed that specifically examine the relationship between the use of GeoGebra, self-efficacy, hard work, and critical thinking to students' mathematics learning achievement. This research is necessary because it can provide a more comprehensive understanding of the psychological and cognitive factors that influence critical thinking skills and how these skills impact students' mathematics learning achievement.

Integrating GeoGebra, developing self-efficacy, hard work character, and critical thinking skills can create a more effective and enjoyable mathematics learning environment. GeoGebra can present material visually and interactively, thus increasing student understanding and motivation. GeoGebra can also increase students' self-efficacy by providing a successful and meaningful learning experience (Anajihah, Sulistyowati, Harini, Agustito, &

Nugraheni, 2023). In addition, challenging and supportive learning can develop students' hard work character and critical thinking skills. Thus, integrating these factors can significantly improve students' mathematics learning achievement.

Based on the description above, there are four objectives for this study. First, the direct effect of using GeoGebra and self-efficacy on hard work will be tested. Second, testing the direct effect of using GeoGebra, self-efficacy, and hard work on math learning achievement. Third, testing the direct effect of using GeoGebra, self-efficacy, hard work, and critical thinking on math learning achievement. Fourth, testing the indirect effect of using GeoGebra, self-efficacy on math learning achievement through hard work, and critical thinking. Based on the previous explanation, there are four hypotheses for this study. First, using GeoGebra and self-efficacy directly affects hard work. Second, there is a direct effect of using GeoGebra, self-efficacy, and hard work on math learning achievement. Third, there is a direct effect of using GeoGebra, self-efficacy, hard work, and critical thinking on math learning achievement. Fourth, there is an indirect effect of using GeoGebra and self-efficacy on math learning achievement through hard work and critical thinking.

METHODS

This study uses a type of quantitative research with a correlational design. The correlational research design aims to determine the relationship or relationship between two or more variables without manipulating these variables (Sutama, Hidayati, & Novitasari, 2022). There are three variables in this study: exogenous variables (GeoGebra usage (X_1) and self-confidence (X_2)), intervening variables (hard work character (Y_1) and critical thinking ability (Y_2)), and endogenous variables (math learning achievement (Z)).

The study population was all grade XI students in one of the high schools in Boyolali who used GeoGebra in learning mathematics, with a total population of 252 students. The sample size was determined using the Slovin formula with a precision of 5%, resulting in 156 respondents (Sevilla, Ochave, Punsalan, Regala, & Uriarte, 1984).

Data collection in this study was carried out using two types of instruments, questionnaires and test questions, which were tested for validity and reliability. The variable of GeoGebra usage is measured through a questionnaire that assesses the frequency of use and the skill level in utilising the software, with a Likert measurement scale to ensure the data obtained is quantitative and structured (Hohenwarter & Preiner, 2007). The self-confidence variable was adapted from the Academic Self-Efficacy Scale (Bandura, 1997), which allows researchers to measure students' confidence level in facing mathematical challenges. Meanwhile, the hard work character variable was measured using a questionnaire based on the theory of Daryanto and Darmiatun (2013), which includes aspects of perseverance and consistency in learning. The critical thinking ability variable instrument was the watson-glaser critical thinking appraisal-based test, measuring students' analysis, evaluation, and inference abilities (Facione, 2011). Mathematics learning achievement was measured through a test with non-routine questions that measured concept understanding and application to ensure data objectivity.

Data analysis was conducted using inferential methods based on path analysis to test the causal relationship between variables. The parameter estimation of the relationship between the use of GeoGebra, self-confidence, hard work character, critical thinking ability, and mathematics learning achievement is visualised in the path diagram in figure 1.

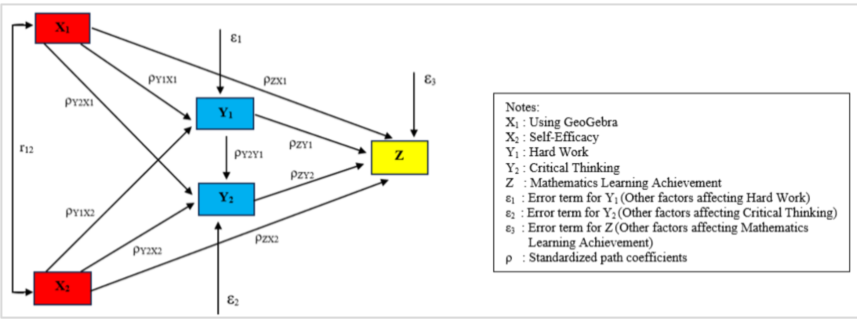

Figure 1. Path Diagram

Based on figure 1, three structural equation models are obtained.

1. Model I
   $Y_1 = \rho_{Y1X1}X_1 + \rho_{Y1X2}X_2 + \varepsilon_1$
2. Model II
   $Y_2 = \rho_{Y2X1}X_1 + \rho_{Y2X2}X_2 + \rho_{Y2Y1}Y_1 + \varepsilon_2$
3. Model III
   $Z = \rho_{ZX1}X_1 + \rho_{ZX2}X_2 + \rho_{ZY1}Y_1 + \rho_{ZY2}Y_2 + \varepsilon_3$

Before conducting inferential statistical analysis through path analysis, prerequisite testing was carried out, including normality, linearity, multicollinearity, and heteroscedasticity (Creswell & Creswell, 2017). The entire analysis process, both prerequisite tests and path analysis, was carried out using SPSS version 22 software.

RESULTS AND DISCUSSION

1. Prerequisite Tests

Table 1. Normality Test of Model I, Model II, and Model III

	Model	Unstandardized Residual
Model I	Asymptotic Significance (2-tailed)	0.183
Model II	Asymptotic Significance (2-tailed)	0.087
Model III	Asymptotic Significance (2-tailed)	0.053

Table 1 shows the normality test results on models I and II using the one-sample kolmogorov-smirnov test. for model I, a significance value (sig.) of 0.183 was obtained, greater than α = 0.05. Model II obtained a significance value (sig.) of 0.087, greater than α = 0.05. At the same time, Model III obtained a significance value (sig.) of 0.053, which is greater than α = 0.05. Thus, it can be concluded that the data is usually distributed.

Table 2. Linearity Test of Model I, Model III, and Model IV

Model	Linearity	Dependent–Independent Variable Pairs	Significance
Model I	**Deviation for Linearity**	Hard Work* Geogebra Usage	0.162
		Hard Work* Self-Efficacy	0.405
Model II	**Deviation for Linearity**	Critical Thinking* Geogebra Usage	0.160
		Critical Thinking* Self-Efficacy	0.174
		Critical Thinking* Hard Work	0.129
Model III	**Deviation for Linearity**	Learning Achievement* Geogebra Usage	0.612
		Learning Achievement* Self-Efficacy	0.062
		Learning Achievement* Hard Work	0.201
		Learning Achievement* Critical Thinking	0.710

Table 2 presents the results of the linearity test in model I, model II, and model III. The results show that for each pair of independent variables in model

I, with hard work as the dependent variable, the significance value (sig.) in deviation from linearity is greater than α = 0.05. Similarly, for each pair of independent variables in model II, with critical thinking as the dependent variable, the significance value (sig.) in deviation from linearity is greater than α = 0.05. And for each pair of independent variables in model III, with learning achievement as the dependent variable, the significance value (sig.) in deviation from linearity is greater than α = 0.05. This indicates that the relationship between each independent and dependent variable in all three models is linear.

Table 3. Multicollinearity Test Model III

Model	Variable	Tolerance	VIF
Model I	Geogebra Usage	0.578	1.731
	Self-Efficacy	0.578	1.731
Model II	Geogebra Usage	0.501	1.994
	Self-Efficacy	0.313	3.199
	Hard Work	0.283	3.538
Model III	Geogebra Usage	0.491	2.035
	Self-Efficacy	0.306	3.265
	Hard Work	0.242	4.131
	Critical Thinking	0.434	2.306

Table 3 presents the results of the multicollinearity test for models I, II, and III. In all three models, each independent variable shows a Tolerance value greater than > 0.1 and a VIF < 10. This indicates the absence of multicollinearity or strong intercorrelation among the independent variables across the models.

Table 4. Heteroskedasticity Test of Model I, Model II, and Model III

Model	Variable	Significance
Model I	Geogebra Usage	0.061
	Self-Efficacy	0.350
Model II	Geogebra Usage	0.069
	Self-Efficacy	0.537
	Hard Work	0.059
Model III	Geogebra Usage	0.195
	Self-Efficacy	0.115
	Hard Work	0.553
	Critical Thinking	0.325

Table 4 shows the results of the heteroscedasticity test in model I, model II, and model III. In the three models, it is found that all independent variables have a significance value (sig.) greater than $\alpha = 0.05$. This means there are no symptoms of heteroscedasticity, or the residual variance of the model is homogeneous (consistent) in the three models.

2. Hypothesis Test

Before testing the hypothesis, it is necessary to determine the magnitude of the path coefficient in each structural model. For this reason, a linear regression test will be carried out on model i, model ii, and model III. The results of the linear regression test for Model I are presented in table 5.

Table 5. Linear Regression Test Model I

Variable Eksogen	Standardized Coefficients Beta	R^2	Significance
Geogebra Usage	0.273	0.717	0.000
Self-Efficacy	0.644		0.000

Based on table 5, the path coefficient value of each variable is obtained, namely $\rho_{YX1} = 0.273$ and $\rho_{YX2} = 0.644$. The residual error value (ε_1) is calculated using theformula $\sqrt{1 - R^2}$ and is obtained as 0.532. In addition, each path coefficient has a significance value (Sig.) that is smaller than $\alpha = 0.05$, so it can be concluded that all paths in model I are significant. In addition, the structural equation of Model I is formulated as $Y = 0.273X_1 + 0.644X_2 + 0.531$.

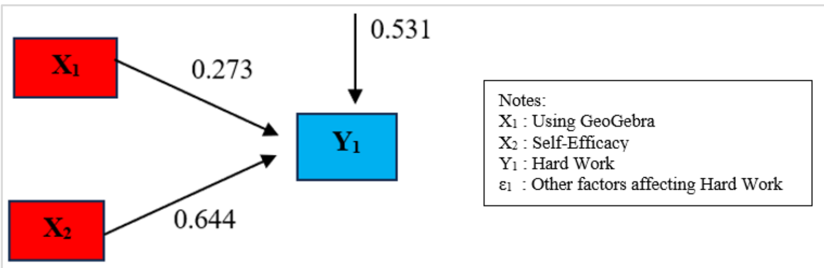

Figure 2. Diagram of Model I

Table 6 presents the findings of the linear regression analysis for model II. The path coefficient value of each variable is obtained, namely $\rho_{ZX1} = 0.134$, $\rho_{ZX2} = 0.168$, $\rho_{ZY1} = 0.507$. The residual error value (ε_2) is calculated using theformula $\sqrt{1-R^2}$and is obtained as 0.824. In addition, each path coefficient has a significance value (sig.) greater than α = 0.05.

Table 6. Linear Regression Test Model II

Variable Eksogen	Standardized Coefficients Beta	R^2	Significance
Geogebra Usage	0.134	0.566	0.079
Self-Efficacy	0.168		0.080
Hard Work	0.507		0.000

Therefore, it can be concluded that there is one significant path in model II, namely the path for hardwork because it has a significance value (sig.) that is smaller than α = 0.05. In addition, the structural equation of model II is formulated as $Z = 0.134X_1 + 0.168X_2 + 0.507Y_1 + 0.831$.

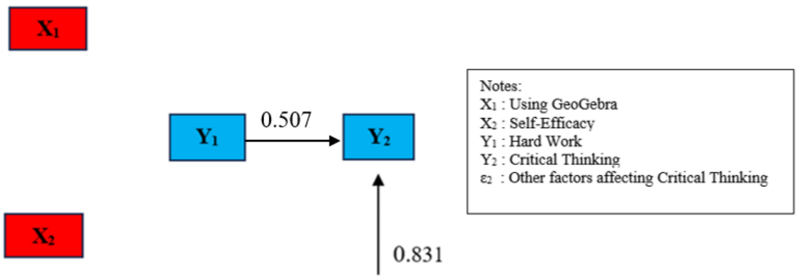

Figure 3. Diagram of Model II

Furthermore, table 7 shows the results of the linear regression test for Model III. The path coefficient value of each variable is obtained, namely ρ_{ZX1} = 0.058, ρ_{ZX2} = 0.053, ρ_{ZY1} = 0.238, ρ_{ZY2} = -0.175. The residual error value (ε_3) is calculated using the formula $\sqrt{1-R^2}$ and is obtained as 0.998. In addition, each path coefficient has a significance value (Sig.) greater than α = 0.05.

Table 7. Linear Regression Test Model III

Variable Eksogen	Standardized Coefficients Beta	R^2	Significance
Geogebra Usage	0.058	0.052	0.606
Self-Efficacy	0.053		0.713
Hard Work	0.238		0.141
Critical Thinking	- 0.175		0.148

Therefore, it can be concluded that all paths in Model III are not significant. In addition, the structural equation of Model III is formulated as $Z = 0.058X_1 + 0.053X_2 + 0.238Y_1 - 0.175Y_2 + 0.998$.

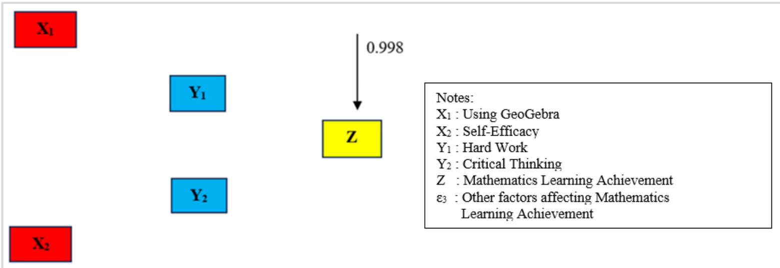

Figure 4. Diagram of Model III

After that, the three hypotheses that have been assumed before will be tested.

First Hypothesis:

H_0: Using GeoGebra and self-efficacy has no direct effect on the character of hard work.

H_a: There is a direct effect of using GeoGebra and self-efficacy on the character of hard work.

Based on table 5, the significance value for the GeoGebra usage variable is $0.000 < \alpha = 0.05$, and self-efficacy is $0.000 < \alpha = 0.05$. Since all significance values are smaller than the significance level (α), H_0 is rejected for each variable. Thus, it can be concluded that using GeoGebra and self-efficacy significantly affects the character of hard work.

The results of data analysis show that the use of GeoGebra and self-efficacy directly affect the character of hard work significantly. The R Square value obtained is 0.717, meaning that the variables' use of GeoGebra and self-efficacy contribute 71.7% to hard work. In comparison, 29.3% is the contribution of other variables outside those studied. Self-efficacy is the variable with the most significant influence on hard work, as indicated by the path coefficient value $\rho_{YX2} = 0.644$. This is in line with the findings of research by Zakariya (2022), which shows that self-efficacy is one of the main internal factors that influence students' hard work, especially in solving non-routine problems that demand perseverance and higher-level thinking strategies. Students with high self-efficacy tend to be more confident in completing complex tasks and show continuous efforts to achieve learning goals.

In addition, using GeoGebra in mathematics learning is also proven to improve students' self-regulation and hard work skills significantly. Zetriuslita, Nofriyandi, and Istikomah (2020) stated that GeoGebra helps students plan, monitor, and evaluate their thinking processes more effectively by visualizing abstract concepts. Similar findings were also presented by Yohannes and Chen (2023), who found that integrating GeoGebra in learning improved concept understanding and encouraged students to be more focused, diligent, and try their best during the learning process.

Second Hypothesis:

H_0: Using GeoGebra, self-efficacy, and hard work do not directly affect critical thinking.

H_a: There is a direct effect of using GeoGebra, self-efficacy, and hard work on critical thinking.

The data analysis showed that using GeoGebra and self-efficacy did not significantly affect critical thinking. Meanwhile, hard work has a significant direct effect critical thinking. The R Square value of 0.566 indicates that the variables of GeoGebra usage, self-efficacy, and hard work contributed 56.6% to the variation in critical thinking. However, this finding also shows that only hard work directly contributes significantly, while the remaining 43.4% comes from other variables outside this research model. In this case, hard work is the variable that has the most significant influence on critical thinking, as indicated by the path coefficient value of $\rho_{ZY1} = 0.507$. This is the opinion of Liu, Huang, and Zhang (2023), who stated that hard work is a key indicator of learning perseverance that directly impacts academic success, especially in completing complex and challenging tasks. Students who demonstrate hard work tend to be more resistant to obstacles and can maintain focus and motivation in the long term.

Meanwhile, using GeoGebra is the variable with the weakest influence on critical thinking, with a coefficient value of $\rho_{ZX1} = 0.134$. This is supported by the opinion of Zakaria, Carol, Hanid, Adnan, Raimi, and Azman (2024), who emphasized that the use of GeoGebra needs to be supported by appropriate pedagogical strategies and teacher skills in integrating it actively in learning. Without a targeted approach, using GeoGebra will only serve as a visual aid without significantly impacting students' conceptual understanding and critical thinking.

Third Hypothesis:

H_0: Using GeoGebra, self-efficacy, hard work, and critical thinking do not directly affect math learning achievement.

H_a: GeoGebra, self-efficacy, hard work, and critical thinking directly affect math learning achievement.

Based on table 7, the significance value for GeoGebra usage is 0.606 > α = 0.05, self-efficacy is 0.713 > α = 0.05, hard work is 0.141 > α = 0.05, and critical thinking is 0.148 > α = 0.05. Since the significance value of all variables is greater than α, H_0 is accepted for each variable. Therefore, it can be concluded that there is no direct effect of using GeoGebra, self-efficacy, hard work, and critical thinking on mathematics learning achievement.

The results of data analysis showed that the variables of GeoGebra usage, self-efficacy, hard work, and critical thinking did not significantly influence students' mathematics learning achievement. The R Square value of 0.052 indicates that the four variables simultaneously only contribute 5.2% to the variation in students' mathematics learning achievement. Thus, the remaining 94.8% is influenced by other variables outside this research model. This finding indicates that although the four variables are theoretically relevant, they have not been proven to significantly contribute directly to improving students' mathematics learning achievement in this study. In this case, hard work is the variable that has the most significant influence on learning achievement, which is indicated by the path coefficient value of ρ_{ZY1} = 0.238. Meanwhile, critical thinking became the variable with the weakest influence on learning achievement, with a coefficient value of ρ_{ZX1} = - 0.175. This is in line with the findings of Wulandari and Kurniawan (2024), who emphasized that critical thinking skills do not always directly impact learning achievement, especially if they are not accompanied by the support of explicit learning strategies in developing these skills. Without an appropriate pedagogical approach, students' critical thinking potential is often not optimally utilized in the context of academic evaluation.

Fourth Hypothesis:

H_0: Using GeoGebra and self-efficacy does not indirectly affect math learning achievement through hard work and critical thinking.

H_a: The use of GeoGebra and self-efficacy has an indirect effect on math learning achievement through hard work and critical thinking.

The direct effect of using GeoGebra on learning achievement is ρ_{ZX1} = 0.058. At the same time, the indirect effect of using GeoGebra on learning achievement is $\rho_{Y1X1} \times \rho_{ZY1}$ = 0.273 × 0.238 = 0.064974. This result shows that the indirect effect is smaller than the direct effect. Thus, H_0 for the GeoGebra usage variable is accepted. Using GeoGebra has no significant indirect effect on math learning achievement through hard work. Then, the magnitude of the direct effect of self-efficacy is ρ_{ZX2} = 0.053. At the same time, the magnitude of the indirect effect of self-efficacy on learning achievement is $\rho_{Y1X2} \times \rho_{ZY1}$ = 0.644 × 0.238 = 0.153272. This result shows that the indirect effect is greater than the direct effect. Thus, H_0 for the self-efficacy variable is rejected. Thus, self-efficacy significantly indirectly affects math learning achievement through hard work.

The direct effect of using GeoGebra on learning achievement is ρ_{ZX1} = 0.058. At the same time, the indirect effect of using GeoGebra on learning achievement is $\rho_{Y1X1} \times \rho_{ZY2}$ = 0.273 × (- 0.175) = - 0.047775. This result shows that the indirect effect is smaller than the direct effect. Thus, H_0 for the GeoGebra usage variable is accepted. There is no significant indirect effect of using GeoGebra on math learning achievement through critical thinking. Then, the magnitude of the direct effect of self-efficacy is ρ_{ZX2} = 0.053. Meanwhile, the indirect effect of self-efficacy on learning achievement is $\rho_{Y1X2} \times \rho_{ZY2}$ = 0.644 × (- 0.175) = - 0.1127. This result shows that the indirect effect is smaller than the direct effect. Thus, H_0 for the self-efficacy variable is accepted. Thus, self-efficacy does not significantly affect math learning achievement through critical thinking.

CONCLUSION

This study examines the effect of using GeoGebra, self-efficacy, hard work character, and critical thinking skills on students' mathematics learning achievement. The results showed that the use of GeoGebra and self-efficacy significantly influenced the character of hard work, with a contribution of 71.7%, where self-efficacy was the dominant factor. However, the four variables did not have a significant direct influence on math learning achievement, with a combined contribution of only 5.2%. Further analysis revealed that self-efficacy had a significant indirect effect on learning achievement through the character of hard work, although this effect was relatively small. Meanwhile, critical thinking skills showed a weak and insignificant negative effect. These findings highlight the importance of hard work character as a key factor, although it is not strong enough to be a full mediator in improving learning achievement. This study recommends educators to not only focus on integrating technology such as GeoGebra and strengthening self-efficacy, but also develop more holistic learning strategies, including pedagogical approaches that encourage active student engagement and exploration of other variables that may be more influential, such as teaching methods or learning environments. Thus, efforts to improve mathematics learning achievement can be more effective and sustainable. This study has several limitations that need to be considered in interpreting the findings, namely mediation analysis only compares the magnitude of the coefficient without a more rigorous statistical test of mediation such as bootstrapping, so conclusions about the insignificance of the mediation effect need to be interpreted with caution. The study did not control for GeoGebra implementation factors in the classroom that might moderate its effectiveness. Nonetheless, the findings provide a valuable foundation for further research with a more rigorous design and broader scope.

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