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LEARNING INDEPENDENCE AND EDUCATIONAL SOCIAL MEDIA USE IN RELATION TO MATHEMATICAL CRITICAL THINKING AMONG JUNIOR HIGH SCHOOL STUDENTS

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ABSTRACT

Improving students' mathematical critical thinking has become one of the central priorities in mathematics education. However, limited evidence has examined the combined contribution of learning independence and educational social media use among Indonesian junior secondary students. The relationships among the variables were examined through a quantitative correlational study that included all 122 eighth-grade students using the total sampling method. Data collection relied on validated questionnaires and a mathematical critical thinking assessment, while the analysis employed Pearson correlation and multiple linear regression techniques. The results showed that learning independence ($r = .407$, $p < .001$) and educational social media use ($r = .435$, $p < .001$) were both positively associated with mathematical critical thinking. Together, both variables explained 34.6% of its variance ($R^2 = .346$, $p < .001$). These findings provide empirical evidence that learning independence and educational social media use complement each other in supporting mathematical critical thinking and suggest that mathematics instruction should integrate self-regulated learning with purposeful educational technology use.

Keywords: Mathematical Critical Thinking, Educational Social Media, Self-Regulated Learning, Mathematics Education, Junior Secondary Students.

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PRELIMINARY

One of the primary objectives of contemporary mathematics education is to cultivate students' mathematical critical thinking. Beyond acquiring computational competence, learners are expected to interpret mathematical concepts, examine relationships among ideas, assess alternative solution strategies, draw evidence-based conclusions, and defend their reasoning logically (OECD, 2023; Facione, 2015). These higher-order cognitive abilities are increasingly important for addressing complex real-world problems and making informed decisions in an era characterized by rapid technological advancement. Therefore,

critical thinking is consistently regarded as a fundamental dimension of effective mathematics learning (Ennis, 2018; Paul & Elder, 2019).

Despite its importance, many students continue to experience difficulties with mathematical tasks requiring higher-order thinking. Results from PISA 2022 indicate that Indonesian students performed below the OECD average in mathematics, particularly on reasoning and problem-solving tasks (OECD, 2023). This situation has been linked to instructional practices that emphasize procedural knowledge rather than conceptual understanding and analytical reasoning (Hattie, 2023; Schoenfeld, 2020). Previous studies have also shown that students' critical thinking develops less effectively when classroom instruction provides limited opportunities for inquiry, discussion, and reflective learning (Muis et al., 2022; Dinsmore & Alexander, 2023).

A similar condition was identified at SMP IT Al-Ikhwan. Classroom observations and students' formative mathematics assessments showed that approximately 68% of eighth-grade students scored below the minimum mastery criterion (KKM = 75) on Higher-Order Thinking Skills (HOTS) questions, although most performed adequately on routine procedural tasks. These findings indicate the need to identify factors that support the development of students' mathematical critical thinking.

Learning independence has been widely acknowledged as a key personal attribute that contributes to students' academic success. Because it reflects the principles of self-regulated learning, independent learners actively plan their learning goals, monitor their progress, and evaluate learning outcomes. These behaviours strengthen students' ability to examine mathematical problems critically, formulate logical conclusions, and defend their reasoning with appropriate justification (Schraw & Gutierrez, 2022; Muis et al., 2022). Consequently, learning independence has consistently been associated with the development of higher-order thinking skills and stronger academic performance.

At the same time, advances in digital technology have substantially changed how students interact with educational resources. Social media applications such as YouTube, WhatsApp, and Instagram have evolved beyond communication tools to become valuable learning environments that support mathematics education through multimedia content, collaborative discussion, and information sharing (Tang et al., 2021; Greenhow & Chapman, 2020). When used strategically for educational purposes, these platforms encourage students to explore multiple mathematical ideas and problem-solving approaches that strengthen critical thinking abilities (Pimmer et al., 2023; Al-Rahmi et al., 2022). However, their

effectiveness depends largely on students' ability to engage actively and purposefully with the available learning resources.

Although previous studies have examined learning independence and educational social media use, several research gaps remain. First, few studies have investigated both variables simultaneously as predictors of mathematical critical thinking. Second, empirical evidence involving Indonesian junior secondary school students is still limited, particularly in the context of the Merdeka Curriculum. Third, most previous studies have focused on general academic achievement or overall critical thinking rather than mathematical critical thinking. Therefore, the combined contribution of learning independence and educational social media use to students' mathematical critical thinking requires further investigation.

This study addresses these gaps by examining the relationships among learning independence, educational social media use, and mathematical critical thinking among eighth-grade students at SMP IT Al-Ikhwan. Specifically, it investigates the relationship between each independent variable and mathematical critical thinking, as well as their combined contribution, to provide empirical evidence supporting mathematics learning in technology-enhanced educational environments, this study tests the following hypotheses:

H_1: Learning independence is positively and significantly associated with students' mathematical critical thinking.

H_2: Educational social media use is positively and significantly associated with students' mathematical critical thinking.

H_3: Learning independence and educational social media use jointly and significantly predict students' mathematical critical thinking.

METHODS

Research Design

A quantitative correlational research design was employed to explore the associations among learning independence, educational social media use, and mathematical critical thinking. This design was selected because it allows the investigation of naturally occurring relationships without manipulating the study variables or introducing experimental treatments (Creswell & Creswell, 2018; Fraenkel et al., 2018). To determine the extent to which each predictor, as well as their combined influence, explained variation in students' mathematical critical thinking, the collected data were analyzed using multiple linear regression.

Participants and Research Setting

The study was conducted at SMP IT Al-Ikhwan in Medan, Indonesia, during the second semester of the 2025/2026 academic year. The research involved the entire population of 122 eighth-grade students enrolled at the school. Given the relatively small population size, a total sampling strategy was implemented, allowing every eligible student to be included in the study. The final sample comprised 122 participants aged 13 to 15 years, consisting of 58 boys and 64 girls. According to Hair et al. (2022), this sample size is adequate for multiple linear regression analysis with two independent variables.

Research Variables

The study investigated two independent variables and one dependent variable. Learning independence (X_1) referred to students' ability to plan, regulate, monitor, and evaluate their own learning processes with minimal dependence on external guidance. Educational social media use (X_2) referred to students' purposeful use of social media platforms for academic activities, including accessing instructional materials, participating in academic discussions, and viewing educational videos related to mathematics learning. The dependent variable, mathematical critical thinking (Y), was defined as students' ability to interpret mathematical information, analyze problems, evaluate solution strategies, draw logical conclusions, and justify mathematical reasoning.

Research Instruments

The level of learning independence was measured using a 15-item questionnaire developed by the researchers based on Panadero's (2017) Self-Regulated Learning (SRL) framework. The questionnaire captured four core dimensions: planning, self-monitoring, self-evaluation, and self-regulation. Participants indicated their responses on a four-point Likert scale, with response categories ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). Negatively worded items were reverse scored before statistical analysis.

Educational social media use was measured using a separate 15-item questionnaire developed from the educational social media frameworks introduced by Tang et al. (2021) and Greenhow and Chapman (2020). The instrument focused on students' use of social media to facilitate mathematics learning. Responses were collected using the identical four-point Likert response format applied in the previous instrument.

Mathematical critical thinking was assessed through a researcher-designed essay test consisting of ten open-ended items. The instrument was constructed based on Facione's (2015) critical thinking framework while remaining consistent with the Grade VIII Merdeka Curriculum. Five dimensions were evaluated, namely interpretation, analysis, evaluation,

inference, and self-regulation. Each response was scored using an analytic rubric with a score range of 0 to 4 for every item.

Instrument Development, Validation, and Reliability

Prior to the pilot implementation, all research instruments underwent a content validation process involving a panel of experts. The purpose of this review was to verify that the instruments adequately reflected the theoretical constructs intended for measurement. The expert panel comprised one mathematics education academic and two experienced mathematics teachers from junior high schools. The reviewers evaluated each instrument with respect to content relevance, construct suitability, completeness, and linguistic clarity. Ratings were assigned using a four-point scale ranging from 1 (not appropriate) to 4 (highly appropriate). Content validity was subsequently established by calculating the overall Aiken's V coefficient (Aiken, 1985).

Table 1. Content Validity and Reliability of the Research Instruments

Instrument	Overall Aiken's V	Interpretation	Pearson Validity (r)	Cronbach's Alpha
Mathematical Critical Thinking Test	0.714	Good	0.401–0.698	0.76
Learning Independence Questionnaire	0.667	Good	0.423–0.712	0.82
Educational Social Media Use Questionnaire	0.711	Good	0.451–0.789	0.79

The results (table 1) indicated that the Mathematical Critical Thinking Test obtained an overall Aiken's V coefficient of 0.714, the Learning Independence Questionnaire obtained 0.667, and the Educational Social Media Use Questionnaire obtained 0.711. These coefficients indicate good content validity, suggesting that the three instruments adequately represented their intended constructs and were suitable for pilot testing after incorporating the revisions recommended by the experts.

Following the content validation stage, the developed instruments were evaluated through a preliminary field trial before being implemented in the main study. The pilot trial involved 30 Grade IX students from a different junior high school who were excluded from the primary sample. Its purpose was to verify the psychometric quality of the instruments by examining both item validity and internal consistency.

Item validity was established through Pearson's Product-Moment correlation analysis. The correlation coefficient for each item was compared with the critical value (r = 0.361), and every item exceeded the required criterion. The obtained validity coefficients

ranged from 0.401 to 0.698 for the Mathematical Critical Thinking Test, 0.423 to 0.712 for the Learning Independence Questionnaire, and 0.451 to 0.789 for the Educational Social Media Use Questionnaire.

To evaluate internal consistency, Cronbach's alpha coefficient was calculated for each instrument. The Mathematical Critical Thinking Test produced an alpha coefficient of 0.76, while the Learning Independence Questionnaire and the Educational Social Media Use Questionnaire obtained coefficients of 0.82 and 0.79, respectively. Because all reliability coefficients were greater than the commonly accepted benchmark of 0.70 (Nunnally & Bernstein, 1994), the three instruments demonstrated satisfactory reliability and were considered appropriate for use in the primary data collection.

Data Collection Procedure

We scheduled the data collection across the first two weeks of May 2026. Prior to launching the study, our team first sought clearance from the school authorities, and concurrently, we acquired informed consent from the students' parents or guardians. All participating students received clear verbal and written explanations that their involvement was optional and that their data would be treated with full anonymity and strict confidentiality. The initial session involved distributing the questionnaires during regularly scheduled classes, which took students approximately 45 minutes to finish. One week post-survey, we arranged a separate 60-minute proctored period for the critical thinking assessment, overseen jointly by ourselves and our field assistants. Crucially, throughout both meetings, our interaction with the students was limited to clarifying logistical aspects; we offered zero guidance regarding the substantive questions on either instrument.

Data Analysis

IBM SPSS Statistics Version 24 was employed to process and analyze the research data. The analysis began with descriptive statistics to describe the distribution and general characteristics of each variable by presenting measures of central tendency and variability, including the mean, standard deviation, minimum value, maximum value, and score distribution.

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Table 2. Interpretation of Score Categories

Variable	Low	Moderate	High
Learning Independence (X_1)	24 - 31	32 - 39	40 - 47
Social Media Use (X_2)	25 - 32	33 - 39	41 - 48
Mathematical Critical Thinking Skills (Y)	13 - 16	17 - 20	21- 24

To facilitate the interpretation of descriptive statistics, the total scores of each variable were classified into three categories: low, moderate, and high. As detailed in Table 2, the score intervals for these categories were established based on the observed score ranges of each research instrument. These categories (see Table 2) were subsequently used as the reference framework for interpreting the mean scores presented in the results section.

The suitability of the regression model was verified before hypothesis testing by conducting several diagnostic procedures. These procedures included assessments of residual normality, multicollinearity, heteroscedasticity, linearity, and autocorrelation to confirm that the data fulfilled the assumptions required for multiple linear regression.

The multiple linear regression model used in this study is expressed as follows:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+ \dots +\beta_nX_n+\varepsilon \quad (1)$$

where:

- Y = dependent variable,
- β_0= intercept (constant),
- $\beta_1, \beta_2, \beta_3, \dots \beta_n$ = regression coefficients,
- $X_1, X_2, X_3, \dots , X_n$ = independent variables,
- ε = error term.

The relationships between the predictor variables and mathematical critical thinking were first explored through Pearson's Product-Moment correlation. Subsequently, multiple linear regression was applied to estimate both the independent and combined predictive effects of learning independence and educational social media use on students' mathematical critical thinking. Statistical decisions were based on the t-test for individual regression coefficients and the F-test for the overall regression model at the 5% significance level. The explanatory capability of the regression model was interpreted using the coefficient of determination (R^2), which represents the proportion of variance in mathematical critical thinking explained by the predictor variables.

RESULT AND DISCUSSION

RESULT

The findings are presented in four sections: descriptive statistics, assumption testing, correlation analysis, and multiple linear regression analysis. All statistical analyses were performed using IBM SPSS Statistics version 24.

Table 3. Descriptive Statistics Summary

Variable	N	Min	Max	Mean	SD
Learning Independence (X_1)	122	24	46	35.82	4.509
Social Media Use (X_2)	122	25	48	36.08	4.774
Mathematical Critical Thinking Skills (Y)	122	13	24	17.85	2.011

Table 3 presents the descriptive statistics of the research variables. Learning independence and educational social media use showed comparable mean scores, indicating that students generally demonstrated moderate levels of self-directed learning and educational use of social media. Likewise, the average score for mathematical critical thinking suggests that students possessed a moderate level of critical thinking ability. Across all variables, the relatively small standard deviations indicate that participants' responses were reasonably homogeneous, reflecting a fairly consistent distribution of scores within the sample.

Table 4. Results of Assumption Tests for Multiple Regression Analysis

Assumption Test	Indicator	value	criterion	interpretation
Normalitas	Asymp. Sig. (2-tailed)	0.200	> 0.05	Normally distributed
Multicollinearity	Tolerance	0.999	> 0.10	No multicollinearity
	VIF	1.001	< 10	No multicollinearity
Heteroscedasticity	Sig.X_1	0.177	> 0.05	No heteroscedasticity
	Sig.X_2	0.787	> 0.05	No heteroscedasticity
Linearitas X_1-Y	Deviation from Linearity	0.452	> 0.05	Linear
Linearitas X_2-Y	Deviation from Linearity	0.451	> 0.05	Linear

Before testing the research hypotheses, several classical assumption tests were conducted to verify the suitability of the data for multiple linear regression analysis. As shown in Table 4, the residuals were normally distributed (Asymp. Sig. = 0.200). The tolerance and VIF values indicated that multicollinearity was absent, while the Glejser test confirmed that heteroscedasticity was not detected. Furthermore, the deviation-from-linearity values for both independent variables exceeded the significance threshold of 0.05,

confirming that the relationships between the independent variables and mathematical critical thinking were linear. Collectively, these findings demonstrate that all regression assumptions were satisfied.

Table 5. Correlation Analysis of Learning Independence(X_1) and Mathematical Critical Thinking Skills (Y)

Variable	Correlation Coefficient (r)	Sig.	Interpretation
Relationship Between Learning Independence(X_1) and Mathematical Critical Thinking Skills(Y)	0.407	0.001	Positive, significant (moderate)
Social Media Use (X_2) and Mathematical Critical Thinking Skills (Y)	0.435	0.001	Positive, significant (moderate)

As reported in Table 5, Pearson Product-Moment correlation analysis identified significant positive associations between both predictor variables and students' mathematical critical thinking. Learning independence demonstrated a moderate positive correlation with mathematical critical thinking (r = 0.407, p < 0.001), indicating that students with stronger independent learning habits generally exhibited better critical thinking performance. Educational social media use also showed a moderate positive relationship with mathematical critical thinking (r = 0.435, p < 0.001). Although both relationships were comparable in strength, educational social media use displayed a slightly higher correlation coefficient. These results indicate that each predictor variable is positively associated with mathematical critical thinking and provides a sound basis for examining their combined predictive effects using multiple linear regression.

Table 6. Anova Result of Multiple Linear Regression Analysis

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	169.528	2	84.764	31.540	.000
Residual	319.816	119	2.688		
Total	489.344	121			

The ANOVA results presented in table 6 indicate that the multiple linear regression model is statistically significant, F(2,119) = 31.540, p < 0.001. This finding demonstrates that learning independence and educational social media use simultaneously have a significant effect on students' mathematical critical thinking. Therefore, the proposed regression model is appropriate for explaining the relationship between the independent variables and the dependent variable.

Table 7. Results of the Multiple Linear Regression Analysis

Variable	B	β	t	Sig.
constant	5.056		3.120	.002
Learning Independence (X_1)	.177	.396	5.348	.000**
Social Media Use (X_2)	.179	.425	5.735	.001**

The multiple linear regression analysis produced the following regression equation:

$$Y = 5.056 + 0.177X_1 + 0.179X_2$$

Where Y represents students' mathematical critical thinking, X_1 represents learning independence, and X_2 represents educational social media use. The regression equation indicates that both predictor variables have positive relationships with students' mathematical critical thinking. The constant value of 5.056 suggests that when learning independence and educational social media use are held constant at zero, the predicted mathematical critical thinking score is 5.056.

The regression coefficient for learning independence (B = 0.177) indicates that a one-unit increase in learning independence is associated with a 0.177 point increase in mathematical critical thinking, holding educational social media use constant. Similarly, the regression coefficient for educational social media use (B = 0.179) indicates that a one-unit increase in educational social media use is associated with a 0.179 point increase in mathematical critical thinking, assuming learning independence remains constant. Both predictors were statistically significant, with learning independence ($\beta = 0.396$, t = 5.348, $p < 0.001$) and educational social media use ($\beta = 0.425$, t = 5.735, p = 0.001). Furthermore, the standardized coefficients indicate that educational social media use contributed slightly more strongly to students' mathematical critical thinking than learning independence, although both variables made significant positive contributions to the model.

DISCUSSION

Overall, the results demonstrate that both learning independence and educational social media use contribute significantly to students' mathematical critical thinking. The following discussion interprets these findings in light of relevant theories and previous empirical studies.

Learning Independence and Mathematical Critical Thinking

The findings of this study indicate that learning independence is positively and significantly associated with students' mathematical critical thinking ($r = 0.407$, $p < 0.001$). Although the correlation is moderate, the results suggest that students who are more capable of planning, monitoring, and evaluating their own learning tend to demonstrate better

mathematical critical thinking. They are more likely to analyse mathematical problems systematically, evaluate alternative solution strategies, and draw logical conclusions. This finding supports the Self-Regulated Learning (SRL) framework proposed by Panadero (2017), which emphasizes that students who actively regulate their learning processes are better equipped to engage in higher-order thinking.

The present findings are also consistent with the theoretical perspectives of Facione (2015) and Ennis (2018), who argue that critical thinking involves interpretation, analysis, evaluation, inference, explanation, and reflective judgment. Students with greater learning independence continuously monitor and assess their understanding, enabling them to solve mathematical problems more critically and effectively. Therefore, self-regulated learning provides an important foundation for the development of mathematical critical thinking.

The results further support previous studies demonstrating that self-regulated learning enhances students' critical thinking through metacognitive regulation and reflective learning (Muis et al., 2022). Nevertheless, the moderate correlation indicates that learning independence is not the only factor influencing mathematical critical thinking, as instructional quality, prior mathematical knowledge, learning motivation, and learning experiences may also contribute. Importantly, learning independence remained a significant predictor even after educational social media use was included in the regression model, highlighting that effective self-regulation continues to play a crucial role in fostering mathematical critical thinking in technology-supported learning environments.

Educational Social Media Use and Mathematical Critical Thinking

The present study revealed a positive and statistically significant relationship between educational social media use and students' mathematical critical thinking ($r = 0.435$, $p < 0.001$). The moderate correlation, which was slightly stronger than that observed for learning independence, indicates that students who purposefully use social media for educational activities tend to demonstrate higher levels of mathematical critical thinking. This finding suggests that social media can serve as an effective learning resource when it is used to support academic rather than recreational purposes. From the perspective of social constructivist learning theory, digital learning environments encourage knowledge construction through interaction, collaboration, and discussion. By accessing diverse mathematical resources, exchanging ideas with peers, and engaging in academic discussions, students are encouraged to evaluate information critically, compare alternative solution strategies, and justify mathematical reasoning (Greenhow & Chapman, 2020; Pimmer et al., 2023).

The present findings are consistent with previous studies indicating that educational social media enhances students' critical thinking by promoting collaborative learning, knowledge sharing, and active engagement in learning activities (Al-Rahmi et al., 2022; Pimmer et al., 2023). These benefits are further strengthened when students possess adequate self-regulated learning skills, metacognitive awareness, and problem-solving abilities (Panadero et al., 2023). However, the findings should not be interpreted as implying that all forms of social media use automatically improve critical thinking. Entertainment-oriented or excessive social media use may instead lead to distraction, information overload, and superficial information processing. Therefore, the educational value of social media depends not on the amount of time spent online but on students' ability to use digital platforms critically, evaluate information, and engage in meaningful academic activities (Kirschner & De Bruyckere, 2017; Lau, 2023; UNESCO, 2021).

An important contribution of the present study is that it provides empirical evidence for the positive role of educational social media use in supporting mathematical critical thinking among junior secondary school students in Indonesia. Unlike previous studies that primarily examined general social media engagement, this study specifically investigated the educational use of social media within mathematics learning. The findings suggest that the effectiveness of social media depends on students' purposeful use of digital platforms to support learning, reflection, and mathematical reasoning. Overall, these results reinforce the view that educational social media should be integrated as a pedagogical resource capable of facilitating critical inquiry, collaborative problem solving, and deeper conceptual understanding when combined with effective learning strategies (Greenhow & Chapman, 2020; Pimmer et al., 2023).

Simultaneous Effects of Learning Independence and Educational Social Media Use on Mathematical Critical Thinking

The multiple regression analysis showed that learning independence and educational social media use jointly had a positive and significant effect on students' mathematical critical thinking, explaining 34.60% of its variance. These findings indicate that higher-order mathematical thinking is influenced by the interaction of internal learning characteristics and external digital learning environments rather than by a single factor (Muis et al., 2022; OECD, 2023). From the perspective of Self-Regulated Learning and technology-supported learning, learning independence enables students to plan, monitor, and evaluate their learning, while educational social media provides opportunities for collaboration, knowledge sharing, and access to diverse mathematical resources. Together, these factors

support students in evaluating mathematical arguments, constructing logical solutions, and developing deeper conceptual understanding. Consistent with previous studies, Muis et al. (2022) emphasized the role of self-regulated learning in strengthening critical thinking, whereas Pimmer et al. (2023) highlighted the contribution of educational social media to collaborative learning and knowledge construction.

An important contribution of this study is the integration of learning independence and educational social media use into a single explanatory model of mathematical critical thinking. The findings demonstrate that these variables complement one another, with educational social media showing a slightly stronger contribution than learning independence. This suggests that meaningful use of digital platforms can further enhance students' critical thinking when supported by effective self-regulation. Therefore, mathematics teachers should encourage students to become independent learners while guiding them to use social media purposefully as an academic learning resource to strengthen critical thinking, digital literacy, collaboration, and mathematical reasoning.

Implications, Limitations, and Future Research

The present findings emphasize that mathematical critical thinking is shaped by the combined influence of learning independence and educational social media use. Rather than acting independently, these two factors appear to complement one another in supporting higher-order thinking. From a theoretical perspective, the results strengthen the application of the Self-Regulated Learning framework by demonstrating that self-regulation can be enhanced through meaningful engagement with educational social media. Accordingly, mathematics educators should design technology-supported learning experiences that simultaneously foster self-regulated learning, digital literacy, and collaborative knowledge construction.

Several limitations should be taken into account when interpreting these findings. First, the cross-sectional correlational design limits the ability to draw causal conclusions. Second, the study involved participants from only one junior high school, thereby restricting the extent to which the findings can be generalized. Third, the regression model explained 34.60% of the variance in mathematical critical thinking, indicating that a substantial proportion remains attributable to other variables not included in this study. Future investigations should therefore incorporate additional predictors, such as mathematics self-efficacy, instructional practices, classroom climate, learning motivation, and digital competence. Employing longitudinal or experimental research designs across broader educational settings would also strengthen future evidence.

CONCLUSION

The results confirm that learning independence and educational social media use are significant predictors of students' mathematical critical thinking. Students who are capable of managing their own learning while using social media intentionally for educational purposes are more likely to demonstrate stronger critical thinking in mathematics. Moreover, the joint contribution of these variables emphasizes that the development of higher-order thinking skills is supported by the interaction between self-regulated learning and meaningful technology use.

The findings also contribute to current research by reinforcing the view that learning independence and educational social media use should be understood as complementary rather than isolated factors influencing mathematical critical thinking. These results imply that successful technology-supported mathematics learning requires not only access to digital platforms but also students' capacity to regulate, evaluate, and apply information critically. Accordingly, mathematics educators should design learning environments that foster self-regulated learning, digital competence, and the purposeful integration of educational technologies.

Although the proposed model explained a meaningful proportion of the variance in mathematical critical thinking, a substantial proportion remained unexplained, indicating that other cognitive, motivational, instructional, and environmental factors also contribute to students' higher-order thinking. Therefore, future studies are encouraged to develop more comprehensive explanatory models involving additional learner and instructional variables to obtain a deeper understanding of the factors that support mathematical critical thinking in contemporary mathematics education

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