EDUCATION AND SCIENCE
JOURNAL OF MATHEMATICS AND SCIENCE EDUCATION
E-ISSN: 2527-7235
Volume 11, Issue 2, October 2026, pp. 1-12
http://ejournal.uki.ac.id/index.php/edumatsains

The Influence of ICT-Based Knowledge Sharing Strategy on Students' Mathematical Reasoning Ability and Independent Learning

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Article Information

Article history:
Accepted: June 25th, 2026
Revised: August 3rd, 2026
Accepted: August 14th, 2026
Available online: October 31st, 2026

https://doi.org/10.33541/edumatsains.v11i2.8474

Abstract

This study aims to: (1) test the effect of students' mathematical reasoning ability with ICT-based knowledge sharing strategy and conventional learning; (2) test the effect of interaction of learning strategy and initial mathematical ability (PMA) on mathematical reasoning ability; (3) at high and low PMA, analyze the difference in students' mathematical reasoning ability with ICT-based knowledge sharing strategy and conventional learning (4) analyze the effect of students' self-regulated learning with ICT-based knowledge sharing strategy and conventional learning. This study uses a quantitative method with a non-equivalent quasi-experimental design involving pretest and posttest for the control and experimental groups. This study was conducted at Darunnajah University, involving 135 students of the Islamic Education Management Study Program in the even semester of the 2025/2026 academic year. The instruments used consisted of a mathematical reasoning test, a self-learning questionnaire, and a PMA test. Data were analyzed using a two-way ANOVA through SPSS 21. The results showed that students taught with ICT-based knowledge sharing demonstrated significantly better mathematical reasoning skills than students taught with conventional methods. In addition, there was a significant interaction between learning strategies and PMA on mathematical reasoning, indicating that students with higher PMA benefited more from the ICT-based knowledge sharing strategy. Furthermore, students in the experimental class demonstrated better self-regulated learning outcomes compared to students in the control class, with PMA also moderating this relationship. These findings confirm that ICT-based knowledge sharing strategies can be an effective alternative to improve students' mathematical reasoning skills and self-regulated learning, especially if tailored to students' initial mathematical ability levels.

Keywords: Knowledge Sharing, ICT, Mathematical Reasoning Ability, Independent Learning, PMA

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1. Introduction

The world has now entered the industry 4.0 era, marked by the rapid development of the digital industry and cyber systems. This development has impacted various aspects of life, including education. In the context of mathematics learning, lecturers are expected to utilize Information and Communication Technology (ICT) and various supporting software because technology-based learning environments can increase student learning autonomy and independent learning. (Rika Handayani, 2024) . The integration of software in this course can be applied in various fields of mathematics, one of which is statistics courses, specifically by using the SPSS 21 application. This software is useful for testing hypotheses and analyzing data quantitatively, making it highly relevant in efforts to improve students' statistical abilities.

However, initial observations by researchers indicate that students' mathematical abilities are still low. Data shows that 56% of students scored below 50, indicating that many errors were still made in answering statistics questions. Furthermore, nearly 70% of students failed to solve the questions correctly because they still used traditional calculations without the help of SPSS 21. Furthermore, many students lacked a grasp of statistical concepts and formulas. Mathematical reasoning skills are crucial to help students understand concepts, draw conclusions, and solve problems logically. (Chimmalee & Anupan, 2026)

In addition to cognitive aspects, emotional aspects also play a crucial role in student learning success. One important emotional aspect is self-regulated learning (SRL), which is an individual's ability to plan, monitor, and control their own learning process. SRL includes students' ability to set learning goals, manage emotions so they don't hinder the learning process, track learning progress, and evaluate their own performance (Letchumanan et al., 2024) . (Abdulrahman et al., 2025, 2026) also added that SRL strategies combined with peer support can improve academic achievement and satisfaction in online mathematics learning. However, many students still face obstacles in implementing self-regulated learning (SRL). This condition is evident in low self-learning initiatives, high dependence on lecturers, and a lack of time management skills and learning strategies (Sui et al., 2024) .

Therefore, a creative learning approach that aligns with current needs is needed. One strategy that is considered promising is ICT-based knowledge sharing. Knowledge sharing is the process of transferring or exchanging knowledge between group members, which can be done through discussion, collaboration, and the use of information technology. (Zhao, 2022) stated that knowledge sharing has a positive impact on students' learning abilities in the 5G and AI era. (Rika Handayani, 2022) found that knowledge sharing plays a mediator in students' innovation processes in the field of information technology. Furthermore, (Handayani et al., 2025) also revealed that knowledge sharing and independent learning behaviors encourage individual students' innovative behavior. (Hou et al., 2026) added that the willingness to share knowledge has a positive impact on students' academic achievement.

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In addition to learning strategies, students' internal factors also influence learning success, one of which is Prior Mathematical Ability (PMA). Research by (Runisah & Ismunandar, 2020) identified a relationship between self-directed learning and mathematical reasoning skills. (Rika Handayani, 2024) examined how technology-based environments influence SRL. (Rocha-Castillo et al., 2025) emphasized the importance of technology integration even with limited internet access. (Nieto-Márquez et al., 2020) also assessed the impact of SRL through educational games on smart platforms. (Utomo, 2022) emphasized the importance of improving TPACK (Technological Pedagogical Content Knowledge) for prospective mathematics educators. (Abdulrahman et al., 2026) emphasized that SRL strategies and peer support are effective in online mathematics learning. Thus, PMA is an important variable to consider in designing learning strategies.

Although various studies have demonstrated the benefits of knowledge sharing and SRL separately, a research gap remains. Despite these valuable contributions, to date no study has specifically investigated the simultaneous effects of ICT-based knowledge sharing strategies, particularly the use of SPSS 21 as a technological tool, on mathematical reasoning and self-regulated learning. Furthermore, the potential moderating role of Prior Mathematical Ability (PMA) in this relationship has not been examined in the context of statistics learning. The shortcomings of previous research lie in three main weaknesses. *First*, previous studies treat knowledge sharing and SRL as separate constructs without integrating them into a comprehensive model. *Second,* most studies focus on general ICT use without specifying specific software tools such as SPSS 21, which are highly relevant for statistical analysis. *Third*, previous studies have primarily examined PMA as a direct predictor or as a variable associated with metacognitive strategies, but none have positioned PMA as a moderator that interacts with instructional strategies to influence learning outcomes. Consequently, the interactive dynamics between ICT-based strategies, students' prior mathematical abilities, and their reasoning and self-regulation abilities remain largely uncharted.

To address these limitations, this study offers novel contributions in three distinct ways. *First,* it integrates knowledge-sharing strategies with SPSS 21 as a specific and contextual ICT tool in statistics learning, rather than treating ICT in a general way. *Second,* it simultaneously measures the influence of these strategies on two dependent variables, mathematical reasoning and self-regulated learning, providing a more holistic understanding of their impact. *Third*, and most importantly, it introduces Prior Mathematical Ability (PMA) as a moderating variable, revealing whether the effectiveness of ICT-based knowledge-sharing strategies depends on students' prior mathematical abilities. This moderation approach goes beyond simply describing relationships and offers a more nuanced model explaining how and for whom these strategies work best.
Therefore, this study aims to examine the impact of ICT-based knowledge sharing strategies on mathematical reasoning and self-regulated learning (SRL) abilities, as well as their reciprocal relationship with PMA. The expected scientific contribution is to produce an innovative statistical learning model with a high level of sophistication and a broad impact on the development of mathematics education in the digital era.

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2. Method

This study used a quantitative approach through a quasi-experimental method. The research design used a nonequivalent pretest-posttest control group design. Two groups were included in this design: (1) the experimental group received an ICT-based knowledge sharing strategy, and (2) the control group underwent conventional expository learning. Both groups received a pretest before the treatment and a posttest after the treatment. This study was conducted at Darunnajah University, Jakarta. The target population was all Darunnajah University students. The target population was fourth-semester students of the Islamic Studies Education Management study program in the 2025/2026 academic year. Sampling was carried out using a multistage sampling technique. This procedure resulted in 135 students who were divided into two groups: the MPI 4A (morning) group as the experimental class and the MPI 4B (afternoon) group as the control class. To analyze the impact of learning strategies and PMA on mathematical reasoning ability, a 2x2 factorial design was used, as follows:

Table 1.
This research design uses a 2 x 2 factorial (the relationship between learning strategies and PMA on mathematical reasoning abilities).

PMA Initial Mathematics Ability (B)	Learning Strategy (A)	
	ICT-Based Knowledge Sharing Strategy (A1)	Expository Strategy (A2)
Height (B1)	A1 B1	A2 B1
Low (B2)	A1 B2	A2 B2

The researchers also wanted to examine the relationship between ICT-based Knowledge Sharing Strategies and self-regulated learning (SRL). In this study, students were treated using ICT-based Knowledge Sharing Strategies (C1), and students were treated using conventional learning (C2).

Table 2.
Research design with 2x1 factorial (relationship between ICT-based knowledge sharing strategies and self-directed learning)

Learning strategies	
ICT-Based Knowledge Sharing Strategy (C1)	Conventional Learning Strategy (C2)
C1	C2

This design will evaluate the impact of learning methods on students' initial mathematical reasoning abilities and independent learning, namely:

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a. First Effect (A1 and A2): Differences in mathematical reasoning abilities between students taught using ICT-based knowledge sharing strategies and students taught using conventional learning methods.
b. Interaction Effect (A x B): The impact of the interaction between learning methods and PMA (Initial Mathematical Ability) on mathematical thinking ability.
c. Simple Effect: Differences in mathematical reasoning ability between students taught using ICT-based knowledge sharing strategies and conventional learning methods with high PMA (A1B1 and A2B1), and with low PMA (A1B2 and A2B2).
d. Second Effect (C1 and C2): Differences in independent learning of students who were given ICT-based knowledge sharing strategies compared to students who were given conventional learning methods.

This instrument was previously validated by five mathematicians: three lecturers and two colleagues. The instrument was then piloted on students from various study programs who had previously received the same material. Validity and reliability tests were conducted to validate the instrument. This hypothesis aims to test whether ICT-based knowledge sharing strategies affect students' mathematical reasoning abilities and self-regulated learning.
After conducting the PMA test to categorize high and low PMA by arranging respondents based on their PMA scores, from highest to lowest. To obtain high and low groups, we determine $33\frac{1}{3}\%$ where these numbers are sufficiently contrasting but also reliable. The research sample consisted of four classes, each divided into two groups, each with $33\frac{1}{3}\%$ students with high and $33\frac{1}{3}\%$ low PMA.

3. Results and Discussion

Analysis of Initial Mathematics Ability Scores (PMA)

Students' Prior Mathematical Ability (PMA) was measured by administering a test before the treatment was given. The average PMA before the treatment did not differ significantly between the experimental class that received the ICT-based knowledge sharing strategy (mean = 59.224) and the control class that received conventional learning (mean = 58.103). The variance of the experimental class was 110.87, while the control class was 103.56. Then, a normality test was conducted to check the distribution of both classes, as presented in Table 3.

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Table 3.
Normality Test of Students' Initial Mathematical Ability

Class	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	df	Signature.	Statistics	df	Signature.
Test	0.103	67	0.075	0.979	67	0.314
Control	0.102	68	0.077	0.976	68	.213

Table 3 shows that the probability values (sig. 0.075 > 0.05 for ICT-based knowledge sharing and sig. 0.077 > 0.05 for conventional methods) indicate that the data are normally distributed. Levene's test for homogeneity of variance (sig. 0.865 > 0.05) confirms that H_0 is accepted, meaning that the variances of the two groups are comparable. The balance test using Sig. (2-tailed) yielded a value of 0.002 < 0.05, indicating that H_0 is rejected, meaning that there is a significant difference in average PMA scores between the experimental and control classes.

This study found that students taught through ICT-based knowledge sharing demonstrated significantly higher mathematical reasoning ability than those taught using conventional methods, consistent with Zhao (2022) and Hou et al. (2026). Theoretically, Social Constructivism (Vygotsky, 1978) explains this, as learning occurs through social interaction and collaboration. Knowledge Sharing Theory (Nonaka & Takeuchi, 1995) further suggests that externalizing tacit knowledge forces students to organize and justify their thinking, thereby strengthening reasoning. Collaborative learning plays a crucial role in developing reasoning. Students engaged in group discussions, peer tutoring, and collaborative problem-solving using SPSS 21 demonstrated improved skills. From the perspective of Social Constructivism, collaborative learning creates a Zone of Proximal Development (ZPD) (Vygotsky, 1978), where students achieve more with peer support. Technology-Enhanced Learning supports this through immediate feedback, data visualization, and asynchronous communication.

A significant interaction effect was found between learning strategies and PMA on reasoning, indicating that students with higher PMA benefited more. Self-Regulated Learning Theory (Zimmerman, 2002) explains this, as students with higher PMA possess stronger self-regulation skills. From a Technology-Enhanced Learning perspective, students with higher PMA process information more efficiently, while students with lower PMA face cognitive overload. According to Knowledge Sharing Theory, students with higher PMA are perceived as more credible sources of knowledge, creating a positive cycle that enhances their reasoning. Students in the experimental class demonstrated better self-regulated learning outcomes than those in the control class, with PMA moderating this relationship, consistent with Abdulrahman et al. (2025, 2026) and Letchumanan et al. (2024). From Self-Regulated Learning Theory, ICT-based environments provide tools for developing self-regulation. Technology-Enhanced Learning offers support such as immediate feedback and progress tracking, although students with higher PMA are better able to utilize these affordances. These findings support an integrated framework that combines Social Constructivism, Knowledge Sharing Theory, Self-Regulated Learning Theory, and Technology-Enhanced Learning. ICT-based knowledge sharing creates an interactive

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environment where students collaboratively construct knowledge, although its effectiveness depends on PMA.

The test results indicate that the PMA conditions are relatively uniform across each category, allowing the sample in this study to be analyzed to evaluate the impact of ICT-based knowledge sharing strategies on students' mathematical reasoning ability and self-regulated learning. The following is the distribution of the sample by PMA category (high and low).

Table 4.

Distribution of Mathematical Reasoning Ability Research Samples Based on High and Low PMA

PMA (B)	Learning Method (A)	
	ICT-Based Knowledge Sharing Strategy (A1)	Conventional Method (A2)
Height (B1)	22	22
Low (B2)	22	22

Based on Table 4, the distribution of PMA samples in the high and low PMA categories is similar. This is due to the following reasons: (1) the PMA test measurement instrument uses the same measurement instrument; (2) the PMA test implementation schedule was not informed in advance, so students were not prepared to face the PMA test. The research sample has been grouped based on the PMA category (high and low). Furthermore, the number of samples in self-regulated learning is based on learning.

Table 5.

Number of Self-Regulated Learning Samples based on learning.

Learning Strategies	
ICT-Based Knowledge Sharing Strategy	Conventional Method (A2)
67	68

Next, the research data was analyzed using SPSS.21 software as follows.

Descriptive Statistical Analysis of Mathematical Reasoning Ability Based on Learning and PMA

Detailed data on students' Mathematical Reasoning Ability (MAR), average test scores, and standard deviations (SD) based on learning methods and initial mathematical abilities (PMA). Showing each level (PMA). In the high PMA category, the group of students who implemented the ICT-based knowledge sharing learning strategy obtained an average score of 69.500. In contrast, students who underwent conventional learning obtained an average score of 58.773.

Furthermore, at the low level of the PMA category, the ICT-based knowledge sharing strategy and conventional learning groups had average KPM test scores of 53.636 and 54.364, respectively. The results of the normality test of Mathematical Reasoning Ability (MRA) data for students based on learning strategies and PMA with Kolmogorov can be presented briefly in Table 6 as follows:

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Table 6.
Normality Test of Mathematical Reasoning Ability Based on Learning Model and PMA

Class	Kolmogorov- Smirnov			Shapiro-Wilk		
	Statistics	df	Signature.	Statistics	df	Signature.
High PMA Experiment	0.137	22	0.200 *	0.926	22	0.103
Low PMA Experiment	0.140	22	0.200 *	0.966	22	0.610
High PMA Control	0.135	22	0.200 *	0.948	22	0.289
Low PMA Control	0.105	22	0.200 *	0.959	22	0.469

Based on table 6, the normality test of Initial Mathematical Ability with a high category shows that the mathematical reasoning ability of both groups has a similar significance (0.200 > 0.05), so the data is normally distributed. Next, a normality test is carried out on the PMA with a low category, where both groups show identical significance (0.200 > 0.05), so the data is normally distributed. This indicates that H0 is accepted, which means further testing is needed. Furthermore, the homogeneity test of Mathematical Reasoning Ability with a high category shows that the mathematical reasoning ability data from the experimental group has a significance value (0.863 > 0.05) and a significance value (0.935 > 0.05) for the control group, so H0 is accepted. Next, a Two-Way ANOVA test is carried out as follows:

Table 7.
*Two-Way ANOVA Test for Mathematical Reasoning Ability Based on Learning * PMA*

Source	Type III Sum of Squares	df	Mean Square	F	Signature.
Corrected Model	3532.045 [a]	3	1177,348	9,683	0,000
Intercept	307036.409	1	307036.409	2525.182	0,000
THURSDAY	2260.409	1	2260.409	18,590	0,000
Learning	550,000	1	550,000	4,523	0.036
PMA*Learning	721,636	1	721,636	5,935	0.017
Error	10213.545	84	121,590		
Total	320782.000	88			
Corrected Amount	13745.591	87			

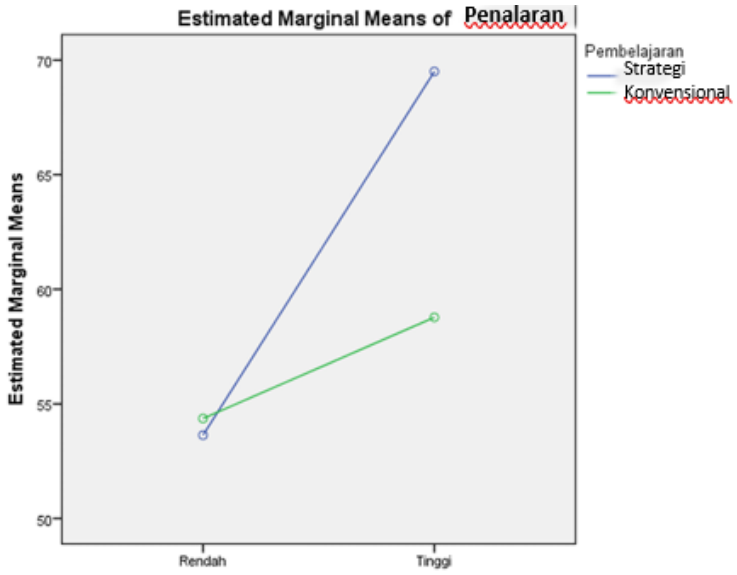
a. R Square = 0.257 (Adjusted R Square = 0.230)

R Square = 0.257 (Adjusted R Square = 0.230)

Based on Table 6, the sig. value of the Two-Way ANOVA calculation results using SPSS 21 above is shown. 0.017 < sig. 0.05, which means H0 is rejected and H1 is accepted. Based on this, there is an interaction factor between learning strategies and PMA. Figure 1 shows the interaction between learning strategies and PMA on mathematical reasoning ability.

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Figure 1.
The Relationship between Learning Strategies and PMA in Mathematical Reasoning Ability



The findings of this study indicate that ICT-based knowledge-sharing strategies are more effective than conventional learning in improving students' mathematical reasoning abilities. This research aligns with research conducted by Zhao (2022), which found that ICT-based knowledge-sharing strategies have a positive impact on students' learning abilities in the 5G and AI era. In the context of mathematics learning, Chimmalee & Anupan (2026) also showed that ICT-based knowledge-sharing strategies can improve students' mathematical reasoning abilities.

Furthermore, Hou et al. (2026) stated that knowledge sharing intention plays a significant role in students' academic success. The results of the study showed a significant interaction between ICT-based knowledge sharing strategies and PMA, which influenced mathematical reasoning ability and served as a mediator of mathematics performance through a self-regulated learning framework. Based on Figure 1, students with high PMA obtained the most significant benefits from ICT-based knowledge sharing strategies compared to students with low PMA. This is in line with research (Runisah & Ismunandar, 2020), which showed that mathematical problem-solving skills are closely related to self-regulated learning through homework behavior, motivation, and metacognition.

Statistical Analysis of Student Independent Learning
Independent Learning Details: Student data obtained from questionnaires. Showing questionnaire filling data in the group using ICT-based knowledge sharing strategies, learning has an average value of 97.068, and the class given conventional learning treatment has an average value of 91.523. The variance of the number of members of the ICT-based knowledge sharing strategy

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learning group is 45.693. The conventional learning group, namely 87.604. The results of the normality test of student self-development questionnaire filling data between those given ICT-based knowledge sharing strategies and those given conventional learning processing using SPSS.21.0 with the Kolmogorov-Smirnov Test can be seen briefly in Table 7 below:

Table 8.
Normality Test of Independent Learning Based on Learning

	Learning	Kolmogorov-Smirnov		
		Statistics	df	Signature.
Independent Learning	ICT-Based Knowledge Sharing Strategy	0.064	67	0.200
	Conventional	0.070	68	0.200

Based on Table 7, the normality test of Independent Learning data using SPSS.21 shows that both experimental class groups of students participating in ICT-based knowledge sharing strategies and conventional learning both have significant differences (0.200 > 0.05). Therefore, both learning groups are normally distributed, and H0 is accepted. Further testing is possible. The results of the homogeneity test show a significant value (0.172 > 0.05), so H0 is accepted. Therefore, it can be concluded that the variance of students' Independent Learning is homogeneous.

To determine the difference in Independent Learning between students who received instruction with ICT-based knowledge sharing strategies compared to conventional learning, the F value was obtained (0.014 < 0.05). This indicates that the hypothesis H0 is rejected. The difference in Independent Learning is also clarified by calculating the t value = 2.482 = 1.980 = t table at the significance level and degrees of freedom (df) = 135, which means H1 is accepted.

4. Conclusion

The research results show that ICT-based knowledge-sharing strategies are more effective than conventional learning in improving students' mathematical reasoning and self-regulated learning (SRL) abilities. This superiority is achieved through the knowledge-sharing process, which allows students to build understanding, test arguments, and obtain feedback collaboratively.

This study also found an interaction between learning strategies and Prior Mathematical Ability (PRA) on mathematical reasoning skills. ICT-based knowledge-sharing strategies provided greater benefits for students with high PRA, while students with low PMAstill needed additional support to achieve optimal benefits. In addition to improving reasoning skills, these strategies were also shown to encourage students' independent learning by increasing initiative, responsibility, and the ability to independently manage and evaluate their learning process in a digital environment.

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Further research will focus on developing learning supports for students with low PRA, as well as longitudinal studies to test the sustainability of these strategies' effects on self-regulated learning. Replication across different courses, digital platforms, and educational levels is also needed to strengthen the generalizability of the findings and develop a theory of ICT-based knowledge sharing in mathematics education.

5. References

Abdulrahman, AA, Husain, SKS, Letchumanan, M., & Yunos, F. (2025). Improving Peer Learning and Feedback Learning Through Independent Learning in Online Mathematics for Academic Achievement and Student Satisfaction. *International Journal of Science, Mathematics and Technology Learning* , *32* (2), 213–237. https://doi.org/10.18848/2327-7971/CGP/v32i02/213-237

Abdulrahman, AA, Husain, SKS, Letchumanan, M., Yunos, F., & Osman, S. (2026). Improving online mathematics learning through self-regulation strategies and peer support. *STEM Education* , *6* (3), 418–438. https://doi.org/10.3934/steme.2026018

Chimmalee, B., & Anupan, A. (2026). The Effect of SRL Strategy with Cloud-Based Combined Approach on Undergraduate Students' Mathematical Reasoning Ability. *International Journal of Information Technology and Education* , *16* (2), 364–371. https://doi.org/10.18178/ijiet.2026.16.2.2509

Hou, H., Ma, L., Wang, D., & Qu, L. (2026). Disentangling the effects of data literacy and knowledge sharing willingness on college students' academic achievement in China: a moderated mediation model. *Asia Pacific Education Review* , *27* (2), 693–704. https://doi.org/10.1007/s12564-024-10010-5

Letchumanan, M., Husain, SKS, & Ayub, AFM (2024). Self-Directed Learning in Online Mathematics Learning Environments: A Systematic Review. *Journal of Online Educators* , *21* (4). https://doi.org/10.9743/JEO.2024.21.4.6

Nieto-Márquez, N.L., Sillaots, M., Martínez, A.C., & Nieto, M. Á. P. (2020). Assessing the impact of self-directed learning using educational games on smart platforms. *Proceedings of the European Conference on Game-Based Learning* , *2020, September* , 408–416. https://doi.org/10.34190/GBL.20.102

Rika Handayani. (2022). The Effect of Generative Learning Model on Students' Mathematical Representation Ability and Self-Efficacy in Junior High School. *Aufklärung: Journal of Education, Social and Humanities* , *2* (1), 31–35.

Rika Handayani. (2024). The Effect of the IMPROVE Method on Mathematical Understanding and Self-Development. *Glasser Journal of Education* , *8* (37).

Rocha-Castillo, S., Pasquel-López, C., & Heredia-Escorza, Y. (2025). Technology integration in indigenous schools without internet access. *Contemporary Educational Technology* , *17* (2). https://doi.org/10.30935/cedtech/15945

Runisah, FG, & Ismunandar, D. (2020). The relationship between independent learning and creative thinking skills in mathematics. *Journal of Physics: Conference Series* , *1657* (1). https://doi.org/10.1088/1742-6596/1657/1/012004

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Sui, C.-J., Yen, M.-H., & Chang, C.-Y. (2024). Investigating the influence of technology-enhanced environment perception on self-regulated learning. *Education and Information Technology* , *29* (1), 161–183. https://doi.org/10.1007/s10639-023-12270-x

Utomo, E. (2022). Synthesis of qualitative evidence-based learning models through design to improve TPACK of prospective mathematics teachers. *Journal of Physics: Conference Series* , *2157* (1). https://doi.org/10.1088/1742-6596/2157/1/012044

Zhao, J. (2022). The Effect of Knowledge Sharing on Students' Learning Ability in the Context of "5G+AI." *International Journal of New Technologies in Learning* , *17* (1), 133–145. https://doi.org/10.3991/ijet.v17i01.28533

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