

The influence of metacognitive strategies on students' mathematical connection abilities and learning independence

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Abstract.

Mathematical connection skills and learning independence remain challenges in the formal education system, particularly among students who rely heavily on procedural memorization rather than deep conceptual understanding. This situation underscores the necessity of developing learning strategies that promote critical thinking awareness and reflection. One such strategy is the application of metacognitive techniques. This study seeks to assess the impact of metacognitive strategies on the development of mathematical connection skills and learning independence among eighth-grade students enrolled in the mathematics department at Al Washliyah Hamparan Perak Private Middle School. Employing a quantitative approach with a quasi-experimental pretest-posttest control group design, the study sample comprises two classes: an experimental group that receives instruction utilizing metacognitive strategies and a control group that receives conventional instruction. The analysis of the data revealed a substantial positive impact of metacognitive strategies on both mathematical connection skills (significance $0.000 < 0.05$) and learning independence (significance $0.001 < 0.05$). The average gain score for mathematical connections was 0.54735 for the experimental group and 0.28264 for the control group. Similarly, the average gain score for learning independence was 0.39870 for the experimental group and 0.19518 for the control group. Consequently, metacognitive strategies have been demonstrated to be an effective tool for enhancing both mathematical connection skills and learning independence. Their implementation in the formal education system is crucial in fostering critical thinking, self-awareness, and independent learning among students.

Keywords:

Metacognitive; independent learning; mathematical connections

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INTRODUCTION

Mathematical connection ability is a fundamental aspect of mathematics learning that significantly enhances students' conceptual understanding (NCTM, 2020; Pambudi et al., 2020; Caviedes et al., 2024). This ability encompasses students' capacity to establish internal and external connections between various mathematical concepts, including their relevance to real-world contexts (NCTM, 2020). Regrettably, in classroom practice, this aspect is frequently overlooked and has not become a primary teaching focus. In fact, profound mathematical comprehension does not solely rely on procedural memorization but also on the ability to discern interrelationships among concepts and apply them to diverse contextual situations. Pambudi et al. (2020)

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demonstrated that students with robust mathematical connection skills tend to demonstrate greater proficiency in solving intricate problems and readily relate mathematical content to real-life experiences, such as those encountered in artistic or construction endeavors. Conversely, students who lack the customary practice of constructing conceptual connections often encounter difficulties in comprehending and utilizing mathematics effectively.

Observations conducted at SMP Swasta Al Washliyah Hamparan Perak corroborate these findings. When presented with problems involving two lines, the majority of students were only able to state that lines k and l intersect because they could visually anticipate that the two lines would intersect upon extension. However, a significant number of students were unable to determine the equations of the lines or their point of intersection. This indicates a deficiency in comprehending several fundamental concepts, including interpreting or sketching graphs of simple algebraic functions on the Cartesian coordinate system, calculating gradients and equations of straight lines, and solving systems of linear equations in two variables. Furthermore, this issue is suspected to be associated with students' lack of familiarity in connecting visual, symbolic, and verbal representations of a concept. The situation is further exacerbated by internal factors such as students' prior knowledge and individual characteristics, as well as external factors such as the quality of teaching at the school (e.g., whether the school is national or international standard). Augie et al. (2023) underscored that numerous students encounter difficulties in linking mathematical concepts they have acquired with practical applications. According to the TIMSS 2019 data, approximately 40% of Indonesian students were unable to connect mathematics to everyday life. This observation underscores the imperative of enhancing mathematics instruction by adopting approaches that promote conceptual connections, such as metacognitive strategies (Maulana et al., 2023).

The Merdeka Curriculum currently implemented in Indonesia emphasizes the significance of developing mathematical connection abilities. This curriculum instructs students to relate mathematical concepts to authentic experiences, enabling them to comprehend the practical relevance of mathematics in daily life (Dewi & Rusman, 2025). Muharomi and Afriansyah (2022) further underscores the importance of effective instruction in establishing connections between mathematical concepts and authentic situations, facilitating students' holistic understanding and application of mathematics. Within this framework, mathematical connection abilities are intrinsically linked to students' self-regulated learning (Chintya et al., 2023). Independent learning in mathematics encompasses students' capacity to manage their learning processes, including setting objectives, devising strategies, executing them, and assessing learning outcomes (Chintya et al., 2023). This skill holds paramount importance in mathematics, often perceived as an intricate subject. Independent learners demonstrate a proactive approach in seeking learning resources, demonstrate a willingness to comprehend unfamiliar concepts, and exhibit a reduced propensity to abandon learning when encountering challenges (Duong et al., 2022). Hasna et al. (2023) posits that independent learning is also associated with heightened intrinsic motivation, which, in turn, contributes to improved academic performance (Sudirman & Panjaitan, 2023). Furthermore, independent learning assists students in identifying their strengths and weaknesses, enabling them to concentrate their efforts on targeted improvements.

In the realm of mathematics education, self-regulated learning assumes a pivotal role in the development of critical thinking and problem-solving abilities. Independent learners tend to establish mathematical connections more effectively, facilitating the understanding and resolution of diverse problems. Isa (2023) underscores that independent learning possess enhanced skills in analyzing problems, designing solutions, and making logical decisions. Hakiki et al. (2023) further emphasize that self-directed learning presents students with opportunities to explore diverse problem-solving strategies, thereby strengthening conceptual comprehension and reflective thinking.

Parallely, independent learning contributes to the character formation of students. Individuals accustomed to independent study often exhibit heightened discipline, responsibility, and perseverance, positively impacting both academic performance and social life (Rahma et al.,

2022). Regrettably, observations at SMP Swasta Al Washliyah Hamparan Perak revealed a concerning trend of low motivation among students towards mathematics. A significant portion perceived mathematics as an arduous and monotonous subject, adversely affecting their independent learning. Their inadequate mastery of fundamental concepts also contributed to a rapid decline in motivation, aligning with the findings that a lack of motivation and conceptual proficiency are primary factors underlying poor mathematics learning outcomes (Sardiman, 2018).

To address these challenges, an instructional approach that simultaneously enhances both mathematical connection ability and independent learning is necessary. Metacognitive strategies have been demonstrated to be effective in assisting students in developing self-awareness and reflecting on their learning processes (Dahiana et al., 2022). According to Aisah and Nurjamin (2021), metacognitive strategies encourage students not only to concentrate on the solutions but also to comprehend the reasoning processes they employ. These strategies comprise two primary components: metacognitive knowledge (students' understanding of effective learning strategies) and metacognitive regulation (the ability to plan, monitor, and evaluate learning processes). By adopting such strategies, students can develop into independent and reflective learners who are adept at connecting various mathematical concepts. Students who are cognizant of their thinking processes are more likely to identify weaknesses, take corrective actions, and optimize conceptual comprehension through appropriate approaches. Rahayu and Fauzan (2023), in their study conducted at SMPN 12 Padang, discovered that motivation and independent learning collectively accounted for 36% of the variance in students' mathematics achievement.

Students with metacognitive skills possess not only the ability to design more effective learning strategies but also the capacity to overcome mathematics anxiety and cultivate a positive attitude towards the subject matter. Research indicates that students with lower levels of mathematics anxiety demonstrate enhanced proficiency in applying metacognitive strategies (Januar et al., 2023). Furthermore, metacognitive knowledge functions as a mediator, mitigating the detrimental effects of anxiety on mathematics learning outcomes (Chandra & Royanto, 2019). In practical terms, educators can facilitate the development of metacognition through diverse methodologies, including reflective questioning, small-group discussions, and problem-based learning. Additionally, educators can establish supportive learning environments that foster a sense of safety among students, enabling them to express their strategies and challenges openly. Consequently, the application of metacognitive strategies in mathematics instruction can serve as a potent means to enhance mathematical connection abilities and promote independent learning. Ultimately, this approach contributes to improved academic performance and equips students with the necessary skills to navigate future challenges effectively.

METHOD

This study employed a quasi-experimental design, which involves the comparison of two groups: an experimental group and a control group. The experimental group received treatment through the application of metacognitive strategies, while the control group was taught using conventional instruction. The quasi-experimental design was deemed appropriate because it allows researchers to examine causal relationships within natural classroom settings, particularly when random assignment of individual students is not feasible. This design has been widely recommended in educational research due to its ability to balance internal validity with practical considerations in real teaching contexts (Creswell & Creswell, 2018; Fraenkel et al., 2019).

The participants of the study were drawn from the population of all eighth-grade students at SMP Swasta Al Washliyah Hamparan Perak. Two classes were randomly selected from this population to serve as the sample. Class 8-A was designated as the experimental group, while class 8-B functioned as the control group. Random sampling was employed to reduce the likelihood of selection bias and ensure comparability between the two groups in terms of academic background and classroom characteristics. This approach aligns with recommendations in educational research methodology, where random selection of intact groups is often utilized when full randomization is not feasible at the individual level (Fraenkel et al., 2019; Gall et al., 2007).

To gather the necessary data, three research instruments were employed. Firstly, a mathematical connection ability assessment was administered to evaluate students' internal and external ability to relate mathematical concepts. Secondly, a learning independence questionnaire was utilized to assess students' autonomy in managing their learning processes, including goal setting, strategy planning, and progress monitoring. Lastly, an observation sheet was employed to document students' learning activities and responses during the implementation of metacognitive strategies. The synergistic use of these instruments provided a holistic perspective of students' cognitive, affective, and behavioral engagement within the learning process.

Data were collected through classroom assessments, surveys, and direct observation. The research methodology was implemented in three phases. The preparation phase encompassed the creation and validation of instruments to ascertain their suitability for the study. The implementation phase entailed conducting teaching and learning activities in the experimental and control classes in accordance with the allocated treatments. Lastly, the conclusion phase involved the compilation, organization, and preliminary review of the data garnered from both groups.

The data analysis employed a combination of quantitative and qualitative methodologies. Quantitative data was initially analyzed using normalized gain scores to assess the extent of improvement in students' learning outcomes. Subsequently, normality and homogeneity tests were conducted to determine the most appropriate statistical procedures. In instances where the data failed to meet the assumptions of normality, the Mann–Whitney test was utilized as a non-parametric alternative. The widespread recommendation of normalized gain in educational research as a reliable measure of instructional effectiveness (Hake, 1998) underscores its suitability. Conversely, non-parametric tests such as the Mann–Whitney are particularly well-suited for data that violate normality assumptions (Field, 2018).

Qualitative data was sourced from observation notes and students' responses to the learning process. These data were analyzed descriptively to provide contextual insights that complemented and supported the quantitative findings (Miles et al., 2014). By integrating both quantitative and qualitative analyses, the study aimed to achieve a comprehensive understanding of the impact of metacognitive strategies on students' mathematical connection ability and self-regulated learning.

RESULTS AND DISCUSSION

To provide a comprehensive analysis of students' mathematical connection abilities prior to and following the intervention, descriptive statistical methods were employed. These methods encompassed calculations of central tendency (mean, median, and mode) and dispersion (minimum, maximum, and standard deviation). A concise summary of the descriptive statistics pertaining to the pretest and posttest scores of mathematical connection ability is presented in Table 1.

Table 1. Distribution of students' mathematical connection ability scores

Statistic	Pretest	Posttest
Number of students	45	45
Minimum score	18	27
Maximum score	34	46
Mean	26.4	37.2
Median	26	37
Mode	26	37
Standard deviation	3.9	3.8

The distribution of mathematical connection scores exhibited a notable enhancement following the implementation of metacognitive strategies. Prior to the intervention, scores were distributed within the range of 18 to 34, predominantly categorized as medium-to-low. However, posttest results demonstrated a shift to a range of 27 to 46, indicating a significant increase in the

number of students achieving higher scores. Notably, the most frequent score experienced a substantial rise from 26 to 39, while the proportion of students scoring above 36 underwent a substantial augmentation. These findings collectively demonstrate the efficacy of metacognitive strategies in enhancing students' independent capacity to establish connections between mathematical concepts.

The distribution of scores across four essay questions further demonstrated that students in the experimental class exhibited enhanced proficiency in relating mathematical concepts to practical scenarios and articulating logical relationships in comparison to the control class, whose scores predominantly fell within the low-to-medium categories. Metacognitive strategies fostered reflective thinking, self-assessment, and the establishment of meaningful conceptual connections, as evident in the distribution of outcomes. Concurrently, the descriptive data pertaining to student learning independence is presented in [Table 2](#).

Table 2. Distribution of students' mathematics learning independence scores

Statistic	Pretest	Posttest
Number of students	45	45
Minimum score	122	129
Maximum score	168	181
Mean	146.4	160.7
Median	148.0	162.0
Standard deviation	11.8	13.2

As evidenced in [Table 2](#), the distribution of independent learning scores following the implementation of metacognitive strategies encompassed a range of values from 129 to 181, with the majority of students situated within the medium-to-high categories. The most prevalent score was 152. Individuals with higher scores exhibited enhanced abilities in planning, monitoring, and evaluating their learning independently. These findings suggest that metacognitive strategies positively impacted students' independent learning, albeit with varying outcomes among individuals. Furthermore, the experimental class demonstrated heightened motivation and confidence in comparison to the control class, which remained stagnant. This indicates that metacognitive strategies not only enhanced cognitive outcomes but also fostered more independent learning attitudes. The comparative analysis of mathematical connection and independent learning abilities between the experimental and control groups is presented in [Table 3](#).

Table 3. Results of mathematical connection ability

Strategy	Types of tests	Mathematical Connection				Learning independent			
		Max	Min	Mean ($\bar{x}$)	SD (stdev)	Max	Min	Mean ($\bar{x}$)	SD (stdev)
Metacognitive	Pretest	34	18	26.69	4.58	168	122	146	13.45
	Posttest	46	30	39.70	4.01	181	139	164	11.09
Conventional	Pretest	34	20	27.09	3.64	159	122	143	10.88
	Posttest	44	27	33.68	5.23	172	129	152	11.97

As evidenced in [Table 3](#), the experimental group demonstrated superior performance compared to the control group in both mathematical connection and independent learning. The experimental group achieved significantly higher mean posttest scores, accompanied by reduced standard deviations, indicating not only enhanced outcomes but also more equitable achievement among students. In contrast, the control group's modest improvements were accompanied by increased variability, suggesting less consistent learning gains. Prior to hypothesis testing, normality and

homogeneity assumptions were scrutinized. The results of the normality test for mathematical connection ability are summarized in Table 4, while the results for independent learning are presented in Table 5.

Table 4. Normality test results for mathematical connection ability

Variable	Group	Kolmogorov–Smirnov			Shapiro–Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest_Connection	Meta	0.084	23	0.200*	0.967	23	0.610
	Control	0.209	22	0.014	0.912	22	0.053
Posttest_Connection	Meta	0.127	23	0.200*	0.959	23	0.436
	Control	0.126	22	0.200*	0.934	22	0.146

Table 4 presents the results of the normality test for mathematical connection ability. In the experimental group (Meta), both pretest and posttest data demonstrate significance values exceeding 0.05 in the Shapiro–Wilk test (0.610 and 0.436, respectively), indicating that the scores adhere to a normal distribution. For the control group, the posttest also conforms to the assumption of normality ($p = 0.146 > 0.05$). However, the pretest in the control group yielded a Shapiro–Wilk significance value of 0.053, slightly exceeding the 0.05 threshold and thus still considered approximately normal. Although the Kolmogorov–Smirnov test for the control group’s pretest yielded $p = 0.014 (< 0.05)$, the Shapiro–Wilk test is more suitable for small sample sizes ($n < 50$). Consequently, the data pertaining to mathematical connection ability can be regarded as generally normally distributed, and the assumption of normality was reasonably met for both groups.

Table 5. Normality test results for mathematics independent learning

Variable	Group	Kolmogorov–Smirnov			Shapiro–Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest_Independent	Meta	0.148	23	0.200*	0.950	23	0.295
	Control	0.171	22	0.094	0.938	22	0.466
Posttest_Independent	Meta	0.131	23	0.200*	0.960	23	0.466
	Control	0.117	22	0.200*	0.975	22	0.815

Table 5 presents the results of the normality test for mathematics independent learning. The Shapiro–Wilk significance values for both the pretest and posttest in the experimental group (0.295 and 0.466) and the control group (0.466 and 0.815) are all greater than 0.05. This indicates that the independent learning scores were normally distributed in both groups at both measurement points. Similarly, Kolmogorov–Smirnov test results were also greater than 0.05, except for the control group’s pretest ($p = 0.094$), which still exceeds the threshold for non-significance.

Combined, the results presented in Tables 4 and 5 unequivocally demonstrate that the assumption of normality was met for both mathematical connection ability and independent learning variables. This validation underscores the appropriateness of employing parametric statistical analyses, such as the independent samples t-test, for hypothesis testing in the current study. Additionally, Levene’s Test, as detailed in Tables 6 and 7, corroborates the homogeneity of variance.

Table 6 presents the homogeneity test results for mathematical connection ability. The results of Levene’s Test for both pretest and posttest scores, based on mean, median, adjusted median, and trimmed mean, all yielded significance values greater than 0.05 (e.g., pretest: 0.212; posttest: 0.114). These findings indicate that the variances between the experimental and control groups were homogeneous both before and after the intervention. Consequently, the assumption

of homogeneity of variances was satisfied, supporting the use of parametric tests such as the independent samples t-test for further analysis.

Table 6. Homogeneity test results for mathematical connection ability

Variable	Levene Statistic	df1	df2	Sig.
Pretest_Connection				
Based on Mean	1.609	1	43	0.212
Based on Median	1.813	1	43	0.185
Based on Median and with adjusted df	1.813	1	42.994	0.185
Based on trimmed mean	1.622	1	43	0.210
Posttest_Connection				
Based on Mean	2.598	1	43	0.114
Based on Median	2.091	1	43	0.155
Based on Median and with adjusted df	2.091	1	41.914	0.156
Based on trimmed mean	2.469	1	43	0.123

Table 7 presents the outcomes of the homogeneity test for independent learning in mathematics. Consistent with the findings regarding mathematical connection ability, all significance values for both pretest and posttest exceeded 0.05 (pretest: 0.196–0.324; posttest: 0.515–0.541). This suggests that the variances in independent learning scores between the experimental and control groups were also homogeneous across both measurement periods.

Table 7. Homogeneity test results for independent learning in mathematics

Variable	Levene Statistic	df1	df2	Sig.
Pretest_Independent				
Based on Mean	1.724	1	43	0.196
Based on Median	0.999	1	43	0.323
Based on Median and with adjusted df	0.999	1	37.680	0.324
Based on trimmed mean	1.732	1	43	0.195
Posttest_Independent				
Based on Mean	0.379	1	43	0.541
Based on Median	0.431	1	43	0.515
Based on Median and with adjusted df	0.431	1	42.803	0.515
Based on trimmed mean	0.418	1	43	0.522

Combining the results from Tables 6 and 7, we can affirm that the assumption of homogeneity of variances was met for both dependent variables—mathematical connection ability and independent learning. This validation enables the application of independent sample t-tests to compare mean differences between groups, thereby ensuring the reliability of the subsequent hypothesis testing. The results of the independent sample t-tests are presented in Tables 8 and 9.

The results of the independent t-test presented in Table 8 demonstrate a substantial impact of metacognitive strategies on the mathematical connection abilities of eighth-grade students enrolled at Al Washliyah Hamparan Perak Private Middle School. The experimental group, which employed metacognitive strategies, achieved an average post-test score of 39.70, accompanied by a standard deviation of 3.99. Conversely, the control group, which engaged in conventional learning, recorded an average post-test score of 33.68, with a standard deviation of 5.23. The significance value (Sig. 2-tailed) of $0.000 < 0.05$ indicates a statistically significant difference between the two groups.

Table 8. Independent t-test results for mathematical connection ability

		Levene's test for equality of variances						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Posttest_Connection	Equal variances assumed	2.598	0.114	4.346	43	0.000	6.01383	1.38262
	Equal variances not assumed			4.320	39.284	0.000	6.01383	1.39195

Given that the Sig. Levene's Test value (0.114) exceeds the significance threshold of 0.05, the "equal variances assumed" row was utilized. This approach yielded a t-count of 4.346 and a confidence interval for the mean difference between 3.22 and 8.80. These findings reject the null hypothesis and support the alternative hypothesis, thereby affirming the efficacy of metacognitive strategies in enhancing students' mathematical connection abilities. This success underscores the metacognitive approach's capacity to foster reflective thinking, establish connections between mathematical concepts and real-world scenarios, and foster a deeper conceptual understanding.

Table 9. Independent t-test results for mathematics independent learning

		Levene's test for equality of variances						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Posttest_Independent	Equal variances assumed	0.379	0.541	3.450	43	0.001	11.86166	3.43776
	Equal variances not assumed			3.444	42.379	0.001	11.86166	3.44368

The results of the independent t-test presented in Table 9 indicate a substantial impact of metacognitive strategies on the learning independence of eighth-grade students at Al Washliyah Hamparan Perak Private Middle School. The experimental group demonstrated an average learning independence score of 164.04 (SD = 11.09), surpassing that of the control group, which achieved an average of 152.18 (SD = 11.97). The statistically significant average difference of 11.86 points is evident from the t-count value of 3.450 at $df = 43$ and the Sig. (2-tailed) value of 0.001 < 0.05 .

The assumption of homogeneity of variance is met as indicated by the Sig. Levene's Test value of 0.541 > 0.05 . Consequently, the interpretation assumes equal variances. The 95% confidence interval for the average difference ranges from 4.93 to 18.79, excluding zero, further reinforcing the significance of the difference. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted. This suggests that metacognitive strategies significantly enhance students' learning independence, fostering greater activity, reflection, and responsibility in the mathematics learning process. Additionally, to evaluate the extent of learning improvement, normalized acquisition scores were subjected to analysis. The findings are presented in Tables 10 and 11.

Based on the t-test results presented in Table 10, the average gain (increase) in students' mathematical connection skills within the experimental group (metacognitive strategies) was 0.54735, accompanied by a standard deviation of 0.1792. This value surpasses the average gain (increase) observed in the control group (regular learning), which stands at 0.28264 with a standard

deviation of 0.2355. This disparity underscores the efficacy of metacognitive strategies in enhancing students' mathematical connection skills.

Table 10. Independent t-test results for normalized gain in mathematical connection ability

		Levene's test for equality of variances						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Gain_Connection	Equal variances assumed	1.706	0.199	4.255	43	0.000	0.264711	0.062206
	Equal variances not assumed			4.230	39.228	0.000	0.264711	0.062583

The independent t-test results yielded a significance value (Sig. 2-tailed) of 0.000, which falls below the significance threshold of 0.05. Consequently, a statistically significant difference was established between the two groups. In contrast, Levene's test yielded a significance value of 0.199, which exceeds the significance threshold of 0.05. This indicates homogeneity of the variances within the two groups. Therefore, the interpretation line adopted assumes equal variances.

Consequently, the null hypothesis (H_0) was rejected, and the alternative hypothesis (H_1) was accepted. Specifically, it was established that there exists a statistically significant enhancement in mathematical connection skills through the implementation of metacognitive strategies. These findings demonstrate that metacognitive strategies not only facilitate conceptual comprehension but also empower students to establish deeper and more structured connections between mathematical concepts. These discoveries reinforce the pivotal role of metacognitive strategies in enhancing the quality of mathematics education at the junior high school level.

Table 11. Independent t-test results for normalized gain in mathematics independent learning

		Levene's test for equality of variances						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Gain_Independet	Equal variances assumed	1.058	0.309	3.644	43	0.001	0.203514	0.055853
	Equal variances not assumed			3.656	42.513	0.001	0.203514	0.055660

Based on the t-test results presented in Table 11, the average gain (increase) in students' mathematics learning independence in the experimental group employing metacognitive strategies was 0.39870, while in the control group utilizing conventional learning, the gain was only 0.19518. This disparity underscores a more pronounced enhancement in learning independence among students who engaged in learning with metacognitive strategies compared to those who participated in conventional learning.

The independent t-test results indicated a significance value (Sig. 2-tailed) of 0.001, which falls well below the critical limit of 0.05. Consequently, the mean difference between the two groups was statistically significant. Conversely, the Levene's Test significance value of 0.309 (>0.05) suggested that the variances of the two groups were homogeneous. Therefore, interpretation was conducted assuming equal variances, which is the row-based approach. The mean difference of 0.203514, accompanied by a 95% confidence interval spanning between

0.090875 and 0.316152, which excludes the zero value, further corroborates the significant difference.

Consequently, it can be concluded that metacognitive strategies significantly contribute to the enhancement of mathematics learning independence among eighth-grade students at Al Washliyah Hamparan Perak Private Middle School. This strategy fosters students' active, reflective, and responsible learning processes, thereby empowering them to acquire learning independence. Overall, the results of the four hypotheses tested in this study indicate that metacognitive strategies are viable as an effective and innovative learning approach to enhance mathematical connection skills and student learning independence at the junior high school level.

The findings of this study indicate that the implementation of metacognitive strategies substantially enhanced students' mathematical connection abilities and self-regulated learning. These outcomes align with previous research that underscores the significance of metacognitive awareness in augmenting problem-solving and conceptual comprehension. For instance, Hake (1998) underscored the efficacy of interactive engagement and reflective strategies in generating higher normalized gains compared to conventional instruction. Similarly, Chandra and Royanto (2020) discovered that metacognitive knowledge functions as a mediator, mitigating the detrimental effects of mathematics anxiety on learning outcomes. The present study corroborates these conclusions by demonstrating that students exposed to metacognitive strategies attained greater conceptual connections and learning autonomy compared to those enrolled in conventional classrooms.

The substantial enhancement in mathematical connection abilities is also consistent with the theoretical framework proposed by the National Council of Teachers of Mathematics (NCTM, 2020), which emphasizes the significance of facilitating students' connections between mathematical concepts and real-world contexts. Participants in the experimental group not only demonstrated superior performance on posttests but also exhibited a more uniform distribution of scores, suggesting that metacognitive strategies fostered equitable learning opportunities. This finding aligns with research conducted by Pambudi et al. (2020) and Caviedes et al. (2024), which indicated that students with enhanced mathematical connections exhibited greater proficiency in solving intricate problems and applying mathematics to authentic scenarios.

In addition, the enhancement of independent learning underscores the significance of cultivating learner autonomy within mathematics classrooms. Self-regulated learning theory (Zimmerman, 2002) posits that students who possess the ability to establish objectives, monitor their progress, and regulate their learning strategies are more inclined to attain academic success. The outcomes of this study indicated that students belonging to the experimental group exhibited elevated levels of motivation, confidence, and reflective thinking, which aligns with the findings of Wangguway et al. (2025) and Hasna et al. (2023), which suggest that self-regulated learners demonstrate a propensity to persevere in the face of challenges and cultivate stronger intrinsic motivation. Furthermore, Hakiki et al. (2023) emphasized that independent learning presents students with opportunities to explore a wide range of problem-solving strategies, thereby enhancing reflective thinking and fostering a deeper comprehension of fundamental concepts. These theoretical perspectives and empirical studies collectively reinforce the positive impact of metacognitive strategies observed in the present research.

The dual improvement in both cognitive and affective domains is noteworthy. While numerous previous studies have primarily focused on academic achievement, the present study demonstrates that metacognitive strategies also promote positive learning attitudes and behaviors. This is particularly pertinent in contexts such as Indonesia, where international assessments like TIMSS 2019 indicated that approximately 40% of students encountered difficulties in connecting mathematics to real-world scenarios (Mullis et al., 2020). By explicitly engaging students in reflection and self-monitoring, metacognitive strategies facilitate the bridging of the gap between procedural learning and comprehending the subject matter, providing a practical solution to address challenges in mathematics education.

Overall, the findings indicate that integrating metacognitive strategies into instructional practices possesses the potential to simultaneously address both academic and motivational challenges. This aligns with constructivist perspectives on learning, which emphasize the active construction of knowledge through reflection and connection-building rather than passive reception (Vygotsky, 1978). By fostering students' reflective and independent learning abilities, metacognitive strategies not only enhance immediate mathematical outcomes but also equip students with essential skills for lifelong learning and problem-solving in broader contexts.

CONCLUSIONS

Based on the research findings, metacognitive strategies demonstrated a substantial impact on students' mathematical connection skills. The experimental group, which received metacognitive strategies, exhibited significantly higher average post-test scores compared to the control group. Moreover, the enhancement in gain scores suggests that these strategies facilitate students in establishing more structured and meaningful connections between mathematical concepts. This indicates that implementing metacognitive strategies can enhance conceptual connections and foster a deeper understanding of mathematical concepts.

Additionally, metacognitive strategies significantly influence students' learning independence. The results indicated that both the final scores and the increase in gain scores for independent learning were higher in the experimental group than in the control group. This strategy encourages students to develop self-reflective and independent learning abilities, assuming responsibility for their own learning process. Students are trained to plan, monitor, and evaluate their learning steps, thereby becoming better equipped to handle academic challenges independently.

Overall, metacognitive strategies constitute an effective learning approach for enhancing two crucial aspects of mathematics learning: mathematical connection skills and independent learning. The success of this strategy is evident not only in its statistically significant outcomes but also in its contribution to shaping students' learning styles to be more focused and competitive. Consequently, metacognitive strategies warrant implementation as an innovative alternative in the mathematics learning process at the junior high school level.

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