

The effects of realistic mathematics education and direct instruction on students' mathematical critical thinking abilities: Considering levels of mathematical resilience

Ghany Taufik Sidik¹, Sufyani Prabawanto^{2*}

¹Department of Primary Education, Universitas Pendidikan Indonesia, West Java, Indonesia

²Department of Mathematics Education, Universitas Pendidikan Indonesia, West Java, Indonesia

*Correspondence: sufyani@upi.edu

Received: Apr 26, 2026 | Revised: Jul 20, 2026 | Accepted: Aug 26, 2026 | Published Online: Oct 5, 2026

Abstract

Indonesian elementary school students' mathematical critical thinking abilities (MCTA) remain suboptimal, highlighting the need for more effective instructional approaches. However, limited evidence has compared the effectiveness of Realistic Mathematics Education (RME) and Direct Instruction (DI) while considering students' mathematical resilience (MR). This study aimed to examine the effects of RME and DI on students' MCTA while considering their MR levels. A quantitative quasi-experimental design was employed with 34 fifth-grade students from an elementary school in Padalarang Village, Indonesia. The intervention consisted of three 70-minute instructional sessions. Data were collected using an MCTA test and an MR questionnaire and analyzed using descriptive and inferential statistics. Students in both groups showed significant improvements in MCTA. Although the RME group achieved slightly higher MCTA acquisition than the DI group, the difference was not statistically significant. However, RME produced significantly greater MCTA improvement than DI. Students with different MR levels showed significant differences in both MCTA acquisition and improvement, and MR had a significant positive effect on MCTA. No significant interaction effect was found between the learning approach (RME and DI) and MR. Overall, both RME and DI effectively improved students' MCTA, with RME yielding greater improvement regardless of students' MR levels.

Keywords:

Mathematical critical thinking abilities, Mathematical resilience, Realistic mathematics education

How to Cite:

Sidik, G. T., & Prabawanto, S. (2026). The effects of realistic mathematics education and direct instruction on students' mathematical critical thinking abilities: Considering levels of mathematical resilience. *Infinity Journal*, 15(4), 1061-1088. <https://doi.org/10.22460/infinity.v15i4.p1061-1088>

This is an open access article under the [CC BY-SA](#) license.



1. INTRODUCTION

Mathematics is one of the fundamental disciplines in elementary education because it equips students with the knowledge, reasoning, and problem-solving skills needed to understand patterns, solve real-world problems, and make informed decisions in everyday life

(OECD, 2023). In the twenty-first century, mathematics education is expected to foster higher-order thinking skills that enable students to address increasingly complex and authentic problems (Demircioglu et al., 2023; Lemon & Taylor, 2026). Therefore, mathematics instruction should provide meaningful learning experiences that engage students in developing conceptual understanding instead of simply memorizing formulas and procedures.

Mathematical critical thinking abilities (MCTA) refer to students' ability to interpret mathematical information, analyze arguments, evaluate evidence, draw logical inferences, explain reasoning, and regulate their thinking when solving mathematical problems (Facione, 1990). These abilities enable students to make reasoned judgments and solve mathematical problems based on logical and reflective thinking. MCTA is essential in the 21st century because it helps students remember and understand mathematical concepts, apply mathematics to problem-solving, develop analytical abilities, and make logical decisions (Demircioglu et al., 2023; Lemon & Taylor, 2026). By thinking critically and mathematically, one can analyze metacognitive problems to arrive at the right solution (Anthonysamy et al., 2024; Kurudirek et al., 2026; Parawansa et al., 2026; Wardana et al., 2024). In contemporary mathematics education, the development of MCTA is increasingly viewed as a multidimensional process involving cognitive, affective, and behavioral components (AlAfnan, 2025; DiNapoli, 2023). Students are expected to interpret problems, evaluate information, justify reasoning, and reflect on their thinking processes (Sutama et al., 2022). These competencies are better developed through instructional practices that emphasize contextual inquiry, collaborative reasoning, and meaningful student participation rather than passive knowledge transmission.

The Programme for International Student Assessment (PISA) mathematics framework indicates that students in Indonesia continue to experience difficulties in mathematical reasoning (OECD, 2023). These processes correspond closely to the dimensions of mathematical critical thinking, indicating that mathematical literacy assessed in PISA is closely associated with students' MCTA (Facione et al., 2020). Similarly, the 2026 Indonesian National Academic Competency Test reported that Indonesian elementary school students achieved a national average mathematics score of only 43.41 (Ministry of Primary and Secondary Education, 2026). Consistent with these national findings, Harianja et al. (2023) reported that 6th-grade students at an elementary school in North Tapanuli Regency, North Sumatra, did not demonstrate optimal MCTA, with an average score of 34.8 on the 2D shapes test. These findings suggest that the current level of students' MCTA remains below the expected level. In this context, students' persistence when encountering difficulties becomes one of the factors influencing the development of critical thinking (Muharram et al., 2025). When persistence and confidence are limited, students are more likely to disengage from complex problem-solving tasks, which reduces opportunities to practice higher-order thinking. Furthermore, mathematics learning often involves abstract concepts that require students to construct meaning through connections with prior knowledge and real-life situations (İşözen & Kaçar, 2026). When these connections are not established, students tend to rely on memorization rather than conceptual understanding, thereby weakening their critical thinking (Day et al., 2024). Therefore, instructional strategies should facilitate meaningful learning experiences by encouraging students to actively construct knowledge, test their ideas, and refine their understanding through interaction and reflection (Khan, 2020). Such learning

conditions foster deeper engagement and enhance students' ability to apply mathematical concepts across diverse contexts.

Realistic mathematics education (RME), developed from Freudenthal's view of mathematics as a human activity, encourages students to construct mathematical knowledge through meaningful real-life contexts, guided reinvention, mathematical discussion, and progressive mathematization (Freudenthal, 1973). Through these learning processes, students actively interpret problems, consider alternative approaches to solving them, provide mathematical justification, and evaluate their own reasoning, thereby supporting the development of MCTA. Moreover, contextual problem solving and guided reinvention encourage students to persist when encountering mathematical challenges, develop confidence through successful learning experiences, and regard mistakes as opportunities for improvement. These mechanisms foster self-efficacy, growth mindset, and persistence, which are fundamental dimensions of MR. Therefore, RME is theoretically expected to support the development of both MCTA and MR. Empirical studies have further demonstrated that RME improves students' MCTA and overall mathematics learning outcomes. The RME is chosen because it is specifically designed for mathematics education strategies that relate concepts to life situations (Van den Heuvel-Panhuizen & Drijvers, 2020). The RME can improve students' MCTA and learning outcomes (Hayati et al., 2025; Nursyahidah et al., 2025; Palinussa et al., 2025; Siswantari et al., 2025; Ventistas et al., 2025). Building on this theoretical foundation, it is necessary to compare RME with a more structured instructional approach that remains widely implemented in elementary mathematics classrooms.

The direct instruction (DI) is a well-established instructional approach that emphasizes explicit teaching, systematic content sequencing, guided practice, and immediate feedback to facilitate students' acquisition of foundational knowledge and procedural skills (de Jong et al., 2023). These characteristics make DI particularly effective for novice learners who require structured instructional support before engaging in more complex problem-solving activities (Momdjian et al., 2025). Despite these advantages, mathematics instruction in many Indonesian elementary classrooms continues to rely predominantly on teacher-centered practices that emphasize procedural learning and teacher explanation (Arega & Hunde, 2025; Maryani et al., 2025; Muhaimin et al., 2026). Consequently, DI serves as an appropriate comparison for evaluating whether RME provides additional benefits in developing students' MCTA. Although both RME and DI have demonstrated positive effects on mathematics learning, their effectiveness may vary according to students' individual characteristics. One of the most influential learner characteristics is mathematical resilience (MR), which plays a key role in sustaining students' engagement when learning mathematics. Accordingly, students' MCTA is influenced not only by instructional strategies but also by individual factors such as MR.

MR refers to students' positive disposition to engage with mathematics despite experiencing challenges or setbacks (Johnston-Wilder & Lee, 2024). It encompasses students' willingness to persist, adapt, and continue learning by perceiving mathematical challenges as part of the learning process rather than evidence of personal inadequacy. MR reflects students' capacity to cope with challenges, regulate emotions, and maintain effort when facing mathematical difficulties (Xenofontos & Mouroutsou, 2023). From a psychological

perspective, MR is supported by several interrelated constructs, particularly self-efficacy and growth mindset. Self-efficacy refers to students' beliefs in their capability to successfully perform mathematical tasks (Bandura, 1997), whereas a growth mindset reflects the belief that mathematical ability can be developed through effort, appropriate learning strategies, and persistence (Dweck, 2006). Together, these psychological characteristics encourage students to remain engaged, regulate negative emotions, and persist when confronted with challenging mathematical problems. Students with strong MR tend to approach problems strategically, explore alternative solutions, and learn from mistakes (Johnston-Wilder & Lee, 2024). In contrast, students with lower MR often experience difficulties in maintaining motivation, which can hinder the development of MCTA (Aydın & Erdem, 2023). For this reason, integrating cognitive and affective dimensions is essential in designing mathematics instruction that supports both MR and the development of MCTA. Accordingly, students' level of MR is expected to influence how effectively they benefit from different instructional approaches, particularly RME and DI, in developing MCTA.

Previous studies have consistently demonstrated the effectiveness of RME and DI in improving MCTA. Sidik and Herman (2025) reported that RME significantly enhanced the MCTA of five-grade students in an elementary school in West Java Province, Indonesia, through contextual problem-solving activities. Maryani et al. (2025) showed that DI also improved the MCTA of fourth-grade students in an elementary school in Central Java Province, Indonesia. A comparative study by Susandi and Widyawati (2022) reported that both RME and DI improved the MCTA of sixth-grade students in an elementary school in Central Java Province, Indonesia, although the magnitude of improvement and the learning processes differed according to the instructional characteristics of each approach. Despite these findings, previous studies have examined instructional approaches and students' MR largely as independent factors. Consequently, limited evidence exists regarding whether students' MR influences the comparative effectiveness of RME and DI in improving elementary students' MCTA. This represents an important research gap because students with different levels of MR may respond differently to the same instructional approach. Therefore, this study investigates the effects of RME and DI on fifth-grade students' MCTA while considering three levels of MR (high, moderate, and low), thereby examining whether MR conditions the effectiveness of these instructional approaches. This assumption is theoretically grounded in the role of MR during mathematical problem solving. Students with higher levels of MR are more likely to persist when encountering challenging mathematical problems, tolerate uncertainty, revise ineffective solution strategies, and regulate their thinking throughout the problem-solving process. These characteristics are expected to facilitate deeper mathematical reasoning and, consequently, the development of MCTA.

Students with higher levels of MR are more likely to develop stronger MCTA (Secadron & Tan, 2023; Taja-on et al., 2025). MR is crucial in mathematics because it enhances students' confidence in solving mathematical problems (AlAfnan, 2025; Muñoz et al., 2025; Polydoros et al., 2025; van Viersen et al., 2026; Zanganeh et al., 2025). Developing MCTA and MR remains challenging in elementary education. Students' advanced mathematical thinking remains underdeveloped, while mathematics instruction often emphasizes procedural learning over reasoning, inquiry, and reflective thinking.

Consequently, many students continue to demonstrate relatively low levels of MCTA and MR (Akkan & Horzum, 2024; Arifin et al., 2025; Callaman & Palompon, 2026; Pillero et al., 2026; Wu et al., 2024). Research by Naldi (2023) found that 28 5th-grade students at one elementary school in Bandung, West Java, had an average MR score of 51.04, which was not optimal. Given these challenges, further investigation is needed to determine whether the effects of RME and DI on students' MCTA vary across different levels of MR. To address this gap, this study investigates the effects of RME and DI on fifth-grade students' MCTA while considering three levels of MR (high, moderate, and low). Accordingly, the following research questions are addressed:

- RQ1 : What is the overview of the acquisition of MCTA among 5th-grade students who received instruction through RME and DI?
- RQ2 : Does RME affect the acquisition of MCTA?
- RQ3 : Does DI affect the acquisition of MCTA?
- RQ4 : Is there a difference in the effects of RME and DI on the acquisition of MCTA by considering the MR?
- RQ5 : What are the criteria for improving the MCTA of 5th-grade students who studied with RME and DI?
- RQ6 : Is there a difference in the effects of RME and DI on the improvement of MCTA by considering the MR?
- RQ7 : Is there a positive correlation between the MR scores and the acquisition of MCTA?
- RQ8 : Do MR scores have a positive effect on the acquisition of MCTA?

2. METHOD

2.1. Research Design

This study employed a quantitative, quasi-experimental design using a pretest–posttest control group design combined with a 2×3 factorial design without randomization (Gall et al., 2013). Random assignment of participants was not feasible because the study involved intact fifth-grade classrooms in an elementary school. Therefore, the existing classes were allocated to the RME and DI groups, and pretest scores were analyzed to determine whether the two groups had comparable initial abilities. Figure 1 illustrates the study design and summarizes the sequence of procedures carried out in the experimental and control groups.

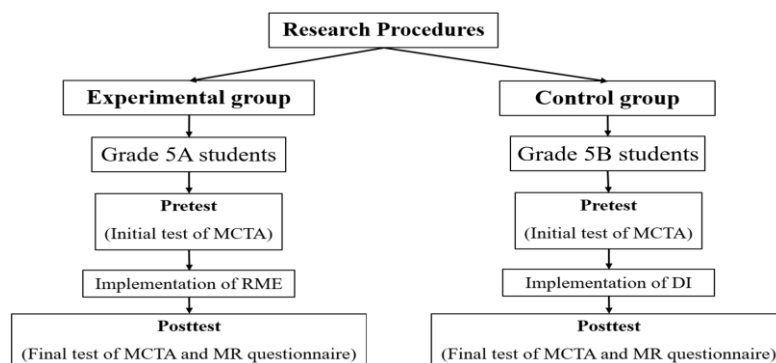


Figure 1. Quasi-experimental research design and procedure

The design aimed to examine the effect of instructional strategies on students' MCTA, while considering students' levels of MR. The instructional intervention differed across the two groups: the experimental group received RME-based instruction, whereas the control group followed DI. Students' initial MCTA was assessed through a pretest administered before the intervention. After the intervention, MCTA was reassessed using a posttest, and students completed the MR questionnaire to identify their MR levels.

2.2. Participants

The participant cohort comprised 34 fifth-grade students attending an elementary school in Padalarang Village, Indonesia. The research site was identified purposively because it offered two intact Grade 5 classrooms that matched the requirements of the quasi-experimental design. The cohort included 19 girls and 15 boys, with all eligible students participating in the study. Eligibility criteria required that students were officially enrolled in Grade 5, attended the mathematics lessons throughout the intervention, and completed both assessment sessions. An equal number of students participated in each instructional condition, with 17 students following the RME and the remaining 17 following the DI. The experimental (RME) group consisted of 6 boys and 11 girls, whereas the control (DI) group consisted of 9 boys and 8 girls. The sample size was determined by the number of students enrolled in the two intact Grade 5 classrooms available for the study, a common practice in school-based quasi-experimental research when random assignment is not feasible (Ballance, 2024). Accordingly, one intact classroom was assigned to the RME group and the other to the DI group. The same mathematics teacher taught both groups to minimize teacher-related variability. The intervention consisted of three instructional sessions, each lasting 70 minutes. The distribution of students across the MR levels was balanced in both instructional groups, with six students in the high MR category, six students in the moderate MR category, and five students in the low MR category (see Table 1).

Table 1. Distribution of participants across instructional groups and MR levels

MR Level	RME	DI
High	6	6
Moderate	6	6
Low	5	5

Only members of the Grade 5 class who completed the full sequence of research activities, completed both assessment sessions, and participated in the intervention. Students who were absent due to illness during the pretest, posttest, or intervention and therefore had incomplete data were excluded from the final analysis. Consequently, the final sample consisted of 34 students.

2.3. Research Instruments

The instruments used in this study consisted of an MCTA test and an MR questionnaire. The MCTA test was developed based on indicators of MCTA, including interpretation, analysis, exploration, and inference. Each indicator was further elaborated into

sub-indicators, including understanding problems, determining solution strategies, constructing mathematical models, representing ideas, and drawing conclusions. An open-ended assessment focusing on the area and perimeter of rectangles was used to measure students' MCTA. To capture changes in performance, the instrument was administered twice: once before instruction and again after the instructional intervention. Table 2 presents the indicators, sub-indicators, and test items used in the MCTA test.

Table 2. Indicators, sub-indicators, and test items of the MCTA

MCTA Indicators	MCTA Sub-indicators	No	Test
Interpretation	Understanding Problems	1a	A wire, 16 meters long. The entire wire is used to fence a rectangular duck pond. a. What is the measurement of half the perimeter of the rectangular duck pond's fence?
Analysis	Determining Solution Strategies	1b	b. What is the likelihood of the largest size of the rectangular duck pond fence wire that is rectangular?
Exploration	Constructing Mathematical Models	2	A rectangular plywood sheet with an area of 200 m ² will be made into 2 rectangular shapes. Determine the length, width, and area of the 2 resulting rectangles, with the condition that all the plywood is used up!
Inference	Drawing Conclusions	3	Look at Figure 2!

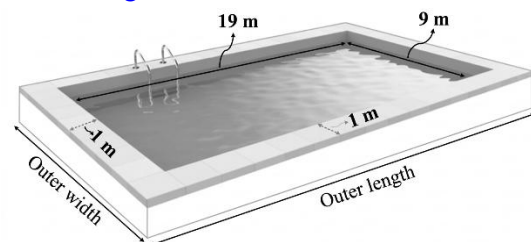


Figure 2. Illustration of the rectangular swimming pool

Mr. Yadi has a rectangular swimming pool. The inside of the pool is 19 meters long and 9 meters wide. A path is 1 meter wide around the pool. What are the length and width of the outside of the pool?

The empirical validity of the MCTA instrument, based on the correlation between students' daily test scores and test results, yielded a coefficient of 0.67, indicating high validity ($0.6 \leq r < 0.8$) (Emerson, 2024). The reliability coefficient for the MCTA test was 0.852, indicating high reliability ($0.71 \leq r < 0.90$) (Emerson, 2024). The MCTA test responses were evaluated using a four-point analytic scoring rubric (Dwijayanti & Wiarta, 2024). The MCTA test was scored using a four-point analytic rubric. A score of 4 was assigned to responses that were correct and complete, demonstrated logical and systematic solution procedures, applied appropriate mathematical concepts or formulas, and provided clear explanations. A score of 3 was assigned to responses that were generally correct with clear solution procedures but

contained minor errors that did not affect the final answer. A score of 2 was assigned to partially correct responses with incomplete solution procedures or errors in mathematical concepts or calculations. A score of 1 was assigned to incorrect or incomplete responses with unclear solution procedures. The MR questionnaire was developed to assess students' MR, including indicators of perseverance, social interaction, openness to new strategies, self-motivation, use of learning resources, and self-regulation. Table 3 presents the indicator items used in the MR questionnaire.

Table 3. Indicator questionnaire items of the MR

No	MR Indicators	Statements
1	Perseverance	I don't give up on studying difficult math material even though it takes a long time.
2	Social interaction	I feel bothered when a friend who is struggling with math asks me for help.
3	Openness to new strategies	I dare to share new ideas when learning in a group.
4	Self-motivation	I looked for an alternative way to solve the math problem when my previous method was unsuccessful.
5	Use of learning resources	I don't try to understand the different ways to solve math problems from various learning sources like books, Google, or videos.
6	Self-regulation	I find it hard to explain my understanding of math to other people.

The MR questionnaire consisted of six items representing six indicators: perseverance, social interaction, openness to new strategies, self-motivation, use of learning resources, and self-regulation. Each item was assessed using a four-point Likert scale (1 = strongly disagree to 4 = strongly agree). The total possible scores ranged from 6 to 24. Following the equal class interval approach for interpreting composite Likert-scale scores (Alkharusi, 2022), students were classified into three levels of MR: low (6–12), moderate (13–18), and high (19–24). The MR questionnaire was validated prior to implementation and confirmed as valid. Furthermore, the reliability analysis using Cronbach's Alpha yielded a coefficient of 0.758, indicating high reliability (Emerson, 2024).

2.4. Research Procedures

The research adopted a quasi-experimental framework in which students' MCTA was measured before and after the instructional intervention. Two existing Grade 5 classrooms participated, with one classroom experiencing RME and the other following DI. The initial assessment provided baseline information on students' MCTA before the intervention commenced. During the intervention phase, both groups studied the same fifth-grade mathematics topic over three 70-minute lessons taught by the same teacher using identical learning objectives and assessment procedures.

The RME group emphasized contextual problems, student exploration, group discussion, and the construction of mathematical concepts. In contrast, the DI group followed a structured sequence consisting of teacher explanation, concept demonstration, worked examples, guided practice with immediate feedback, and independent practice. Thus, the instructional approach was the only difference between the two groups. Students' MR levels

were measured using a questionnaire and categorized into different levels for analysis. After the instructional intervention, students' MCTA improvement was evaluated using a posttest.

2.5. Data Collection and Analysis

Data were collected using the MCTA test administered before and after the intervention, together with the MR questionnaire. The pretest was used to determine students' initial MCTA, while the posttest measured their improvement after the intervention. The collected data were analyzed using SPSS version 31. The data satisfied the assumptions required for parametric analyses. Descriptive statistics were used to summarize students' MCTA, while inferential analyses were used to examine the effects of learning (RME and DI) and levels of MR on students' MCTA.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. An Overview of the Acquisition of MCTA Among 5th-Grade Students Who Received Instruction through RME and DI

The results of the study were analyzed using SPSS, primarily descriptive statistical methods. The outputs are presented in [Table 4](#).

Table 4. Descriptive statistics of the MCTA acquisition of 5th-grade elementary school students who received RME and DI

	Mean	Std. Deviation	Skewness
Pretest before RME	44.14	10.024	0.578
Posttest after RME	70.12	20.985	0.075
Pretest before DI	48.12	6.020	0.310
Posttest after DI	67.59	16.974	0.097

[Table 4](#) presents descriptive statistics for students' MCTA scores before and after the implementation of RME and DI. The mean pretest scores were 44.14 for the RME group and 48.12 for the DI group. Following the intervention, the mean posttest scores increased to 70.12 and 67.59, respectively, indicating improved MCTA in both groups, with the RME group achieving a slightly higher mean score. The standard deviations were higher in the posttest than in the pretest, indicating greater variability in students' MCTA scores after the intervention. In addition, the skewness values ranged from 0.075 to 0.578, indicating that the score distributions were approximately symmetrical with a slight positive skew. Both instructional approaches improved students' MCTA, with the RME group showing a slightly higher posttest mean than the DI group. This finding suggests that RME may better support the development of MCTA by engaging students in contextual and student-centered learning activities (Murni et al., [2026](#)).

3.1.2. The Effect of the RME on the Acquisition of MCTA

To determine the effect of RME on the acquisition of MCTA among 5th-grade students, the conclusion depended on whether the hypothesis stating that "RME has a

significant effect on the acquisition of MCTA among 5th-grade students” was rejected or accepted. To test the hypothesis, paired samples t-test was conducted in SPSS, and the results are shown in [Table 5](#).

Table 5. Paired samples t-test of RME

Comparison	N	r	Sig.	Mean Difference	t	df	Sig. (2-tailed)	Cohen's d
Pretest vs posttest (RME)	17	0.469	0.057	-26	-5.8	16	< 0.001	-1.403

[Table 5](#) shows that the RME group revealed a moderate positive correlation between students' MCTA scores obtained before and after the intervention ($r = 0.469$), with a significance value of 0.057. The observed association failed to achieve statistical significance at the 0.05 level. The paired-samples t-test showed that students' MCTA scores increased significantly from the pretest to the posttest ($p < 0.001$). Therefore, the alternative hypothesis was accepted. This finding demonstrated that the RME significantly affected the MCTA achievement of 5th-grade students. Moreover, the effect size, as measured by Cohen's d , is -1.403, indicating a large effect based on its absolute magnitude. This means that the RME had a substantial effect on students' achievement in MCTA.

The RME significantly affects the acquisition of MCTA of 5th-grade students. The improvement observed in students' MCTA suggests that RME provides an effective learning environment for fostering MCTA. Moreover, the large effect size indicates that the effect is substantial. A possible explanation is that RME emphasizes contextual mathematical problem-solving, thereby helping students understand problems, formulate solution strategies, discuss their reasoning, and draw conclusions more effectively (Johar et al., 2025). This interpretation is supported by previous studies reporting that implementing RME is associated with significant improvements in elementary students' mathematics learning outcomes (Ferreira & Bisognin, 2020; Méndez-Parra et al., 2022; Samritin et al., 2023).

3.1.3. The Effect of the DI on the Acquisition of MCTA

To determine the effect of the DI on the acquisition of MCTA among 5th-grade students, the conclusion depended on whether the hypothesis stating that “RME has a significant effect on the acquisition of MCTA among 5th-grade students” was rejected or accepted. To test the hypothesis, a paired samples t-test is conducted in SPSS, and the results are shown in [Table 6](#).

Table 6. Paired samples t-test of DI

Comparison	N	r	Sig.	Mean Difference	t	df	Sig. (2-tailed)	Cohen's d
Pretest vs posttest (DI)	17	0.295	0.25	-19.471	-4.9	16	< 0.001	-1.198

From [Table 6](#), the paired-samples correlation indicated that the coefficient between students' MCTA scores obtained before and after the intervention in the DI group was 0.295 ($p = 0.250$). This indicated a weak positive correlation, but it was not statistically significant

at $\alpha = 0.05$. The paired-samples t-test confirmed that the posttest MCTA scores were significantly higher than the pretest scores ($p < 0.001$). Therefore, the alternative hypothesis was accepted. Thus, it can be concluded that the DI had a significant effect on the acquisition of students' MCTA. In addition, the paired-samples effect size is Cohen's $d = -1.198$. Based on its absolute magnitude, this result indicated a large effect size, suggesting that the DI substantially influenced students' acquisition of MCTA.

The DI significantly affected the MCTA of 5th-grade students. Although the paired-samples correlation indicated a positive association between students' MCTA scores across the two assessment occasions, the relationship did not reach statistical significance at the 0.05 level. Nevertheless, the paired-samples t-test revealed a significant difference between the two assessment scores, indicating that DI contributed to students' MCTA acquisition. Furthermore, the large effect size suggests that the DI effect is substantial. This may be attributed to the structured nature of the DI, which guides students to practice solving mathematical story problems, discuss their answers, and conclude systematically (de Jong et al., 2023).

3.1.4. The Effect of RME and DI on the Acquisition of MCTA by Paying Attention to the MR

To determine the effect of RME and DI on the acquisition of MCTA by paying attention to the MR of 5th-grade students, the conclusion depended on the rejection or acceptance of the following three hypotheses:

Hypothesis 1 : There is a significant main effect of the learning approach (RME and DI) on the acquisition of MCTA among 5th-grade students.

Hypothesis 2 : There is a significant main effect of students' MR levels on the acquisition of MCTA among 5th-grade students.

Hypothesis 3 : There is a significant interaction effect between the learning approach (RME and DI) and students' MR levels on the acquisition of MCTA among 5th-grade students.

To test the three hypotheses, SPSS was used to perform a general linear model analysis for the two-way ANOVA, and the results are presented in Table 7.

Table 7. Two-way ANOVA results for MCTA acquisition in the RME and DI groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	10238.631 ^a	5	2047.726	38.961	< 0.001
Intercept	154254.751	1	154254.751	2934.925	< 0.001
Learning approach (RME and DI)	46.376	1	46.376	0.882	0.356
MR	10067.948	2	5033.974	95.779	< 0.001
Learning approach (RME and DI) × MR	116.301	2	58.15	1.106	0.345
Error	1471.633	28	52.558		
Total	172895	34			
Corrected total	11710.265	33			

From Table 7, the corrected model was statistically significant ($p < 0.001$), indicating that the overall model explained a significant proportion of the variance in MCTA acquisition. However, the main effect of the learning approach (RME and DI) was not statistically significant ($p = 0.356$), indicating that students taught using RME and DI did not differ significantly in their MCTA acquisition. Although the mean MCTA acquisition score was slightly higher for the RME group (70.12) than for the DI group (67.59), this difference was not statistically significant. In contrast, MR had a significant main effect on MCTA acquisition ($p < 0.001$), indicating significant differences in MCTA acquisition among students with different MR levels. Furthermore, the interaction between the learning approach and MR was not statistically significant ($F = 1.106$, $p = 0.345$), indicating that the effect of the learning approach on MCTA acquisition did not depend on students' MR levels. These findings suggest that MR contributed independently to students' MCTA acquisition rather than moderating the effectiveness of the learning approach. Similar findings were reported by Lubis et al. (2024), who observed differences in mathematical understanding among students with different levels of MR. The model explained 87.4% of the variance in MCTA acquisition ($R^2 = 0.874$), indicating that the combined effects of the learning approach (RME and DI) and MR accounted for a substantial proportion of the variability in students' MCTA acquisition. A Tukey post hoc test is subsequently conducted, and the results are presented in Table 8.

Table 8. Post hoc test output acquisition MCTA

(I) MR	(J) MR	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
High	Moderate	22.08*	2.96	< 0.001	14.76	29.41
High	Low	42.85*	3.104	< 0.001	35.17	50.53
Moderate	High	-22.08*	2.96	< 0.001	-29.41	-14.76
Moderate	Low	20.77*	3.104	< 0.001	13.09	28.45
Low	High	-42.85*	3.104	< 0.001	-50.53	-35.17
Low	Moderate	-20.77*	3.104	< 0.001	-28.45	-13.09

From Table 8, the mean difference in MCTA acquisition between students with high and moderate levels of MR was statistically significant ($p < 0.001$). In other words, there is a significant difference between high and moderate levels of MR in relation to MCTA acquisition because the average MCTA acquisition of students with high MR is greater than that of students with moderate MR. The difference in the average achievement of MCTA also differed significantly between students with high and low levels of MR, with a significance value of less than 0.001, and this value is smaller than 0.05 (α). In other words, there is a significant difference between high and low levels of MR in MCTA acquisition because the average MCTA acquisition of students with high MR is greater than that of students with low MR. Furthermore, the average MCTA achievement differed significantly between students with moderate and low levels of MR ($p < 0.001$), which is below the α level of 0.05. In other words, there is a significant difference between moderate and low levels of MR in MCTA acquisition because the average MCTA acquisition of students with moderate MR is greater than that of students with low MR. Thus, students with high MR demonstrate higher MCTA than those with moderate or low MR. Likewise, the MCTA for students with moderate MR is

higher than that for students with low MR. The estimated marginal means for the MCTA acquisition score are presented in Figure 3.

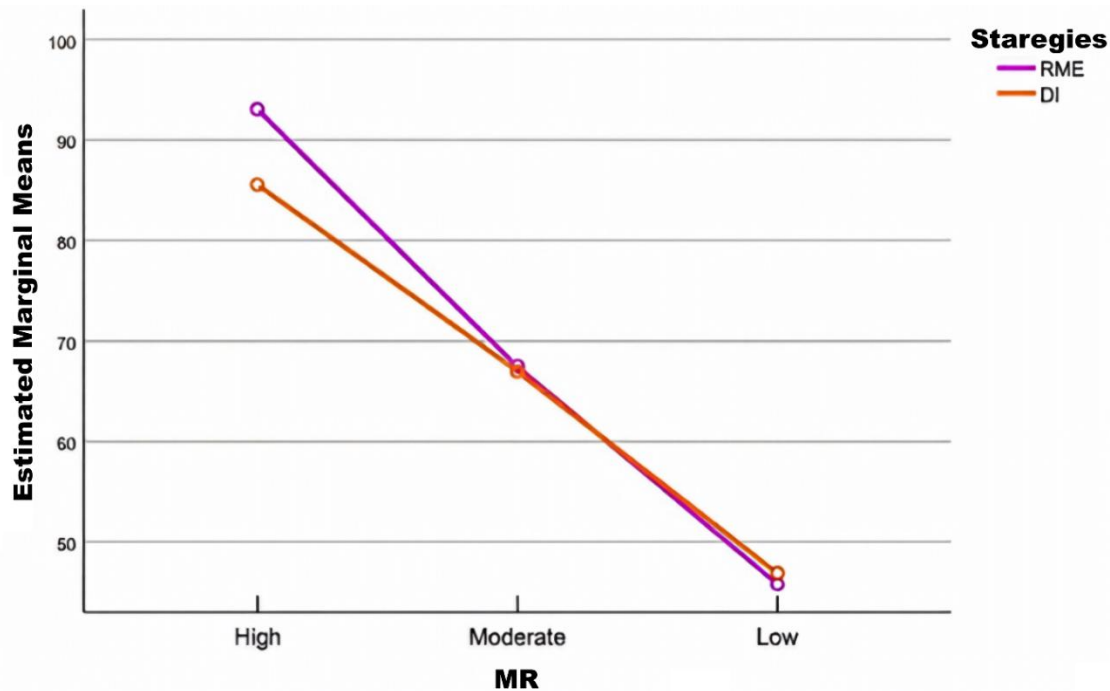


Figure 3. Estimated marginal means of MCTA acquisition scores across instructional strategies and MR levels

Based on Figure 3, the average MCTA of students with high levels of MR who learned through RME was higher than that of students with high levels of MR who learned through DI. The average MCTA of students with moderate MR who learned through RME was the same as that of students with high MR who learned through the DI. In addition, the average MCTA of students with low-level MR who learned through RME is lower than that of students with high MR who learned through the DI.

3.1.5. The Criteria for Improving MCTA from 5th-Grade Students Studying with the RME and DI

To determine the criteria for improving MCTA from 5th-grade students taught using RME and DI, a descriptive analysis of the N-Gain scores was conducted, and the output is presented in Table 9.

Table 9. Descriptive statistics of MCTA improvement criteria from 5th-grade students studying with the RME and DI

Variable	N	Minimum	Maximum	Mean	Std. Deviation
N-Gain in the RME	17	0	1	0.4803	0.35719
N-Gain in the DI	17	0	1	0.3783	0.29988

From Table 9, the mean N-Gain score for the RME group was 0.4803, whereas that for the DI group was 0.3783. The score is in the range of 0.3–0.7, indicating the moderate category. Thus, there is an increase in the MCTA of 5th-grade elementary school students who

studied with the RME and DI in the moderate category. The RME provides a meaningful learning experience through contextual problem-solving and encourages active student participation, thereby improving students' MCTA (Sutarni et al., 2024). As for the DI, learning is more centered on teachers, and students are accustomed to learning using it, thereby improving their MCTA (Umar et al., 2020). The higher gain score in the RME group indicates that student-centered, context-based learning is more effective at fostering deeper understanding and critical thinking. Through the RME, students are actively involved in constructing knowledge, discussing ideas, and connecting mathematical concepts with real-life situations. Meanwhile, although the DI contributes to improvement, its more structured nature may limit students' opportunities to explore alternative solution strategies and engage in higher-order thinking processes.

3.1.6. The Effect of RME and DI on the Improvement of MCTA by Paying Attention to the MR

To determine the effect of RME and DI on the improvement of MCTA by paying attention to the MR of 5th-grade students, the conclusion depended on the rejection or acceptance of the following three hypotheses:

Hypothesis 1 : There is a significant main effect of the learning approach (RME and DI) on the improvement of 5th-grade students' MCTA.

Hypothesis 2 : There is a significant main effect of students' MR levels on the improvement of 5th-grade students' MCTA.

Hypothesis 3 : There is a significant interaction effect between the learning approach (RME and DI) and students' MR levels on the improvement of 5th-grade students' MCTA.

To test the three hypotheses, SPSS analysis was used to fit a general linear model for the two-way ANOVA, and the output is shown in Table 10.

Table 10. Two-way ANOVA results for MCTA improvement in the RME and DI groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	3.039 ^a	5	0.608	31.811	< 0.001
Intercept	5.664	1	5.664	29.416	< 0.001
Learning approach (RME and DI)	0.087	1	0.087	4.574	0.041
MR	2.916	2	1.458	76.304	< 0.001
Learning approach (RME and DI) × MR	0.034	2	0.017	0.893	0.421
Error	0.535	28	0.019		
Total	9.844	34			
Corrected total	3.574	33			

From Table 10, the corrected model was statistically significant ($p < 0.001$), indicating that the model adequately explained the variation in students' MCTA improvement. The learning approach had a significant effect on MCTA improvement ($F = 4.574$, $p = 0.041$), indicating that students taught using RME and DI differed significantly in their MCTA

improvement. Therefore, the alternative hypothesis was accepted. This finding suggests that the choice of instructional approach plays an important role in enhancing students' MCTA. In particular, instructional strategies that emphasize contextual understanding and active student involvement may contribute more effectively to the development of higher-order thinking skills. These results are supported by Susanti et al. (2022), who showed that RME could provide targeted learning stages for students based on mathematical contextual problems, thereby often fostering MCTA compared to traditional methods. Furthermore, MR had a significant effect on MCTA improvement ($p < 0.001$), indicating significant differences in MCTA improvement among students with different MR levels. This finding suggests that students' MR contributes independently to their improvement in MCTA. However, the interaction between the learning approach (RME and DI) and MR was not statistically significant ($p = 0.421$). Therefore, the null hypothesis was not rejected, indicating that no significant interaction effect was found between the learning approach (RME and DI) and MR on the improvement of 5th-grade students' MCTA. This finding suggests that the effectiveness of the learning approach in improving MCTA did not depend on students' MR levels. In other words, although RME produced greater improvements in MCTA than DI overall, this advantage was consistent across students with different levels of MR. This result is supported by the research of Faradillah and Humaira (2021), which found that students with high MR levels had higher MCTA scores than those with moderate or low levels. Students with high MR were able to solve contextual problems in mathematical stories that required a high level of MCTA (Fitriani et al., 2023). The interaction between learning (the DI) and MR is not statistically significant ($p = 0.421$), indicating that the effect of the DI on MCTA acquisition did not depend on students' MR levels. However, previous studies have reported that fourth-grade students taught using the RME demonstrated higher MCTA scores than those taught using the DI, suggesting that differences between instructional strategies may persist independent of MR levels (Susanti et al., 2022). The effect of MR levels (high, moderate, and low) on MCTA acquisition is statistically significant ($p < 0.001$). Differences in students' levels of MR play an important role in their attitudes, strategies, and endurance in acquiring MCTA when solving mathematical word problems (Bacatan, 2024). The R-squared value of 0.850 indicates that RME and DI, together with the level of MR, contributed to the increase in MCTA, with a correlation coefficient of 0.850. This means that 85% of the increase in the MCTA of 5th-grade students is attributable to the (RME and DI) and to the MR level. In the next finding, a post hoc Tukey test is conducted, and the results are shown in Table 11.

Table 11. Post hoc test output improvement MCTA

(I) MR	(J) MR	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
High	Moderate	22.08*	2.960	< 0.001	14.76	29.41
High	Low	42.85*	3.104	< 0.001	35.17	50.53
Moderate	High	-22.08*	2.960	< 0.001	-29.41	-14.76
Moderate	Low	20.77*	3.104	< 0.001	13.09	28.45
Low	High	-42.85*	3.104	< 0.001	-50.53	-35.17
Low	Moderate	-20.77*	3.104	< 0.001	-28.45	-13.09

Based on Table 11, there was a significant difference in the mean improvement in MCTA between students with high and moderate levels of MR ($p < 0.001$). This indicates a significant difference between high and moderate MR levels, where students with high MR showed a greater increase in MCTA than those with moderate MR. This pattern suggests that students' MR levels influence not only their persistence but also the depth of their engagement in MCTS processes. In addition, higher MR appears to support students in sustaining cognitive effort when dealing with complex and non-routine mathematical tasks. Furthermore, students with high MR showed a significantly greater increase in MCTA than those with low MR ($p < 0.001$). Similarly, students with moderate MR demonstrated a significantly greater increase in MCTA than those with low MR ($p < 0.001$). Students with high MR tend to show greater perseverance, a stronger desire to interact and seek new ideas, the ability to build self-motivation from experiences of failure in solving mathematical problems, the initiative to utilize various learning resources, and better self-regulation in developing MCTA (López-Aymes et al., 2020; Rahmi, 2022). These findings confirm that MR plays a critical role in shaping students' learning behaviors and cognitive engagement in mathematics. Students with higher MR consistently demonstrate more active participation in problem-solving processes and are better able to maintain motivation when facing challenging tasks. In contrast, students with lower MR exhibit more limited engagement and require additional instructional support to improve their critical thinking performance.

3.1.7. A Positive Correlation between the MR Score and the Acquisition of MCTA

To determine a positive correlation between the MR score and the acquisition of MCTA of 5th-grade students, the conclusion depended on the rejection or acceptance of the hypothesis, which stated that:

Hypothesis 1 : There is a positive correlation between the MR score and the acquisition of MCTA of 5th-grade students studying with RME.

Hypothesis 2 : There is a positive correlation between the MR score and the acquisition of MCTA of 5th-grade students studying with DI.

To test the first hypothesis, SPSS regression analysis was used, and the output is shown in Table 12.

Table 12. Correlation between MR and MCTA among 5th-grade students taught using RME

Model	R	R ²	Adjusted R ²	SE	F	df	p
1	0.565	0.319	0.273	17.888	7.019	(1, 15)	0.018

From Table 12, the significance value was 0.018, which was less than 0.05 (α), indicating that the alternative hypothesis was accepted, and that the correlation coefficient ($R = 0.565$) was significant. Thus, the hypothesis that there is a positive correlation between the MR score and the acquisition of MCTA of 5th-grade students studying with RME is accepted. Thus, there is a positive correlation between the MR score and the acquisition of MCTA in 5th-grade students who studied with RME. This also meant that $R^2 = (0.565)^2 = 0.319$, or around 32% of the variance in the MCTA of 5th-grade students who studied with RME is

explained by MR. To test the second hypothesis, the same regression analysis procedure was applied, and the output is shown in [Table 13](#).

Table 13. Correlation between MR and MCTA among 5th-grade students taught using DI

Model	R	R ²	Adjusted R ²	SE	F	df	p
1	0.279	0.078	0.016	16.837	1.262	(1, 15)	0.279

From [Table 13](#), the significance value was 0.279, which was greater than the significance level ($\alpha = 0.05$). Therefore, the correlation between MR and MCTA acquisition among 5th-grade students in the DI group was not statistically significant. Accordingly, the alternative hypothesis was accepted, indicating insufficient evidence to conclude that MR was significantly associated with MCTA acquisition in the DI group. The correlation coefficient ($R = 0.279$) indicated a weak positive relationship; however, this association was not statistically significant ($p = 0.279$). The coefficient of determination ($R^2 = 0.078$) indicated that approximately 7.8% of the variance in MCTA acquisition was explained by MR, whereas the remaining 92.2% was attributable to other factors not included in the model. Previous studies, including those by Akkan and Horzum (2024), have suggested that MR may contribute to students' mathematical performance. However, the present findings did not provide sufficient statistical evidence to confirm this relationship within the DI group.

3.1.8. The MR Score has a Positive Effect on the Acquisition of MCTA of 5th-Grade Students

To determine the MR score had a positive effect on the acquisition of MCTA of 5th-grade students, the conclusion depended on the rejection or acceptance of the hypothesis which stated that “there is a positive influence between the MR score and the acquisition of MCTA of 5th-grade students who studied with RME” and “there is a positive influence between the MR score and the acquisition of MCTA of 5th-grade students who study with DI”. To test the hypothesis, the researcher sought a linear regression equation relating the MR factor (x) to the MCTA factor for 5th-grade students in the form $y = a + bx$, where b is the slope (gradient) of the regression line, or the regression coefficient. To test the hypothesis, SPSS statistical analysis related to regression was used, and the output is shown in [Table 14](#).

Table 14. Regression coefficients for the relationship between the MR Score (x) and the acquisition of the MCTA (y) among 5th-grade students taught using the RME

Predictor	B	SE	β	t	p
Constant	-43.235	43.005	—	-1.005	0.331
MR (after treatment using the RME)	2.458	0.928	0.565	2.649	0.018

From [Table 14](#), the constant was -43.235. While the x coefficient was 2.458. Thus, the regression equation was $y = -43.235 + 2.458x$. Because the coefficient x in the equation $y = -43.235 + 2.458x$ was positive (2.458), MR (x) had a positive effect on the MCTA (y) among 5th-grade students who studied with the RME. To test the hypothesis, SPSS regression analysis was used, and the output is shown in [Table 15](#).

Table 15. Regression coefficients for the relationship between the MR Score (x) and the acquisition of the MCTA (y) among 5th-grade students taught using the DI

Predictor	B	SE	β	t	p
Constant	17.897	44.427	—	0.403	0.693
MR (after treatment using the DI)	1.231	1.096	0.279	1.123	0.279

From Table 15, the constant value was 17.897. The coefficient of x was 1.231 and significant. So that a significant regression equation was also obtained, namely, $y = 17.897 + 1.231x$. Because the coefficient x of the equation $y = 17.897 + 1.231x$ was positive (1.231), MR (x) had a positive effect on the MCTA (y) of 5th-grade students who studied with DI. This is consistent with research by Secadron and Tan (2023), which found that MR positively affects a person's MCTA. This result implies that students with higher levels of MR are better able to engage in analytical thinking, even when learning is delivered through a more structured, teacher-centered. In addition, resilient students tend to show greater persistence when facing challenging problems, enabling them to explore multiple solution strategies and reflect on their reasoning. Consequently, MR can be considered a crucial factor in enhancing students' MCTA across different instructional settings.

3.2. Discussion

The results of this study indicate that differences in learning strategies are associated with variations in students' MCTA quality. Both the RME and DI groups demonstrated significant improvements in MCTA following the intervention. The RME group achieved a slightly higher posttest mean MCTA score than the DI group. However, the relatively small descriptive difference suggests that both instructional strategies contributed to students' MCTA development. Although the RME group obtained a slightly higher mean MCTA score than the DI group, this difference was not statistically significant. Nevertheless, the descriptive results suggest that RME may provide greater opportunities for students to engage in contextual problem-solving and active knowledge construction. This can be interpreted from the nature of RME, namely that mathematics learning is linked to meaningful, real-life contexts and encourages active student engagement (Siswantari et al., 2025; Van den Heuvel-Panhuizen & Drijvers, 2020; Ventistas et al., 2025). This environment enables students to construct understanding, analyze problems, and justify their reasoning more effectively. This finding aligns with constructivist learning theory, which argues that knowledge is actively constructed through meaningful experiences (Wibowo et al., 2025). This finding is also supported by previous studies that suggest that RME improves students' higher-order thinking skills (Hayati et al., 2026; Rasyidah et al., 2026).

At the same time, the DI also significantly contributes to MCTA development, albeit through different mechanisms. The structured and systematic nature of the DI helps students organize knowledge, practice problem-solving procedures, and receive immediate feedback. This supports students in building foundational understanding and procedural fluency. These findings are consistent with research by Ndia et al. (2025), which highlighted that the DI is effective in improving learning outcomes through clear instructions and guided practice.

However, its teacher-centered orientation may limit opportunities for deeper exploration and independent reasoning, which are essential for higher-order thinking.

The current results also highlight the important role of MR in the development of students' MCTA. Students with higher levels of MR demonstrated better MCTA than those with moderate or low MR. This suggests that resilient students are more likely to tolerate frustration, sustain cognitive effort, revise unsuccessful problem-solving strategies, and explore alternative representations when solving complex mathematical word problems. These behaviors reflect productive struggle and persistence, enabling students to engage more deeply in mathematical reasoning rather than abandoning challenging tasks prematurely (DiNapoli, 2023). Furthermore, mathematically resilient students tend to exhibit stronger self-regulated learning by monitoring and evaluating their cognitive processes while effectively managing mathematics anxiety. These attributes foster sustained engagement and facilitate deeper mathematical reasoning during complex problem-solving activities (Delima et al., 2024; Purnomo et al., 2024). This interpretation is consistent with the concept of MR, which is a student's capacity to persist, adapt, and remain engaged when faced with mathematical challenges (Johnston-Wilder & Lee, 2024).

Another important aspect revealed in this study is the distribution of students' MCTA scores, which tended to cluster in the low to mid range. This indicates that students are still in the early stages of developing MCTA. This is usually due to their limited experience with tasks requiring higher-order thinking (Jailani et al., 2023). This interpretation is supported by Syamsulrizal et al. (2025), who found that low student MCTA scores are often associated with limited exposure to critical-thinking-oriented problems. Therefore, extensive practice in mathematical problem-solving oriented toward critical thinking is necessary to develop students' analytical and MCTA gradually.

The pattern of MCTA acquisition suggests that RME may facilitate deeper understanding and support students' MCTA through contextual learning experiences. However, the difference between the RME and DI groups was not statistically significant. Learning that emphasizes contextual problem-solving and active participation allows students to connect concepts, discuss ideas, and construct meaning. This aligns with the findings of Sutarni et al. (2024), who stated that student-centered and context-based learning encourages higher-order thinking. Meanwhile, DI also contributed to students' MCTA acquisition through its structured and systematic instructional procedures. However, its teacher-centered nature may limit students' opportunities to explore alternative solutions and engage in more complex reasoning processes (Umar et al., 2020). Furthermore, the positive relationship between MR and MCTA suggests that resilience contributes significantly to students' cognitive development. Students with higher MR tend to demonstrate stronger engagement, better self-regulation, and greater persistence in problem-solving. This supports previous findings that MR is an important predictor of student success in mathematical thinking (Meirong & Mustafa, 2025). Even in a structured learning environment like the DI, MR still plays a role in helping students maintain motivation and engage in analytical thinking.

Another important finding in this study was the absence of a statistically significant interaction between instructional strategy and MR in influencing students' MCTA. The present data did not provide sufficient evidence to conclude that the effectiveness of instructional

strategies differed across levels of MR. Consequently, the findings do not indicate differential effects of RME and DI across MR levels. This finding is consistent with the study by Opesemowo et al. (2025), which reported no significant interaction effect between treatment and gender on mathematics achievement, suggesting that the effectiveness of the instructional approach was not conditional on students' individual characteristics.

This finding also suggests that the effectiveness of the learning approach (RME and DI) did not depend on students' MR levels, but rather on the characteristics of the RME learning strategy itself. The RME supports active engagement, contextual understanding, and knowledge construction (Hayati et al., 2025; Nursyahidah et al., 2025; Palinussa et al., 2025). This interpretation is supported by research emphasizing that a meaningful learning environment in the RME can reduce the influence of individual differences on learning outcomes (Yohannes & Chen, 2024). Thus, both instructional approaches appeared to provide comparable opportunities for students with different levels of MR to develop their MCTA.

Furthermore, although MR had a significant positive effect on MCTA, it did not function as a moderating variable in this study. Recent studies emphasize that MR is suggested to be seen as a dynamic and developable trait. Therefore, a learning environment that supports productive struggle, reflective thinking, and adaptive problem-solving can strengthen students' MR while also fostering higher-order thinking (Ariyanto et al., 2024; DiNapoli, 2023). This implies that enhancing student resilience remains important, but optimizing learning strategies, such as implementing RME, plays a more dominant role in improving students' MCTA in mathematics. This finding aligns with previous research showing that affective factors such as resilience contribute directly to achievement without interacting with learning variables (Doz et al., 2024).

Recent studies increasingly view MR as a dynamic trait that can be strengthened through the right learning experiences (Akkan & Horzum, 2024; Johnston-Wilder & Lee, 2024; Xenofontos & Mouroutsou, 2023). From this perspective, teaching strategies that provide meaningful learning experiences, encourage productive struggle, and promote active engagement can simultaneously boost students' MR and their MCTA. This viewpoint supports current findings, which show that MR directly contributes to students' MCTA without changing the relationship between teaching strategies and those skills. Future studies should further investigate how changes in students' MR over time affect the effectiveness of different teaching approaches by using longitudinal research designs and focusing on individuals. These findings reinforce that both learning strategies and student characteristics independently influence MCTA. The descriptive analysis suggested that students in the RME group achieved somewhat better MCTA outcomes than those assigned to the DI group; however, the difference was not statistically significant. Furthermore, the effectiveness of the instructional approach did not vary significantly across students with different levels of MR. Therefore, integrating contextual and student-centered learning strategies should be prioritized to develop students' higher-order thinking skills.

4. CONCLUSION

The RME group achieved slightly higher MCTA outcomes than the DI group; however, the difference was not statistically significant for MCTA acquisition. Both the RME and DI groups showed significant improvements in MCTA following the intervention. In addition, students' MR had a significant effect on both the acquisition and improvement of MCTA. However, no significant interaction effect was found between the learning approach (RME and DI) and MR. Therefore, both RME and DI were effective instructional strategies for developing students' MCTA. Although the RME group obtained slightly higher MCTA outcomes than the DI group, the difference in MCTA acquisition was not statistically significant. Furthermore, MR contributed independently to students' MCTA development, indicating that cognitive outcomes were influenced by both instructional strategies and students' internal characteristics. For elementary mathematics teachers, these findings suggest that implementing RME, alongside efforts to strengthen students' MR, may provide a meaningful learning environment that supports the development of students' MCTA.

Acknowledgments

The authors would like to thank the fifth-grade students of an elementary school in Padalarang sub-district, Indonesia, for their participation. The authors also acknowledge their cooperation during the research process. The authors thank colleagues and reviewers for their valuable feedback and suggestions.

Declarations

Author Contribution : GTS: Conceptualization, Visualization, and Writing - original draft; SP: Formal analysis, Methodology, Supervision, Validation, and Writing - review & editing.
 Funding Statement : This research received no external funding.
 Conflict of Interest : The authors declare no conflict of interest.
 Additional Information : Additional information is available for this paper.

REFERENCES

- Akkan, S. N., & Horzum, T. (2024). Illuminating the landscape of mathematical resilience: A systematic review. *Journal of Pedagogical Research*, 8(1), 312–338. <https://doi.org/10.33902/jpr.202420093>
- AlAfnan, M. A. (2025). Enhancing educational outcomes using AlAfnan taxonomy: integrating cognitive, affective, and psychomotor domains. *International Journal of Evaluation and Research in Education (IJERE)*, 14(3), 2419–2437. <https://doi.org/10.11591/ijere.v14i3.33147>
- Alkharusi, H. (2022). A descriptive analysis and interpretation of data from Likert scales in educational and psychological research. *Indian Journal of Psychology & Education*, 12(2), 13–16.
- Anthonyamy, L., Sugendran, P., Wei, L. O., & Hoon, T. S. (2024). An improved metacognitive competency framework to inculcate analytical thinking among

- university students. *Education and Information Technologies*, 29(17), 22475–22497. <https://doi.org/10.1007/s10639-024-12678-z>
- Arega, N. T., & Hunde, T. S. (2025). Constructivist instructional approaches: A systematic review of evaluation-based evidence for effectiveness. *Review of Education*, 13(1), e70040. <https://doi.org/10.1002/rev3.70040>
- Arifin, Z., Sukarmin, S., Saputro, S., & Kamari, A. (2025). The effect of inquiry-based learning on students' critical thinking skills in science education: A systematic review and meta-analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(3), em2592. <https://doi.org/10.29333/ejmste/15988>
- Ariyanto, L., Supandi, S., & Kusumaningsih, W. (2024). Students' reflective thinking profiles in problem-solving based on mathematical resilience. *Mosharafa: Jurnal Pendidikan Matematika*, 13(3), 849–860. <https://doi.org/10.31980/mosharafa.v13i3.1435>
- Aydın, M., & Erdem, C. (2023). Profiles of academically resilient students: An examination on TIMSS mathematics data. *Current Psychology*, 42(22), 18916–18927. <https://doi.org/10.1007/s12144-022-03055-5>
- Bacatan, R. J. (2024). Mediating effect of school climate on the relationship between mathematical resilience and disposition of senior high school students. *TWIST*, 19(2), 17–31.
- Ballance, O. J. (2024). Sampling and randomisation in experimental and quasi-experimental CALL studies: Issues and recommendations for design, reporting, review, and interpretation. *ReCALL*, 36(1), 58–71. <https://doi.org/10.1017/s0958344023000162>
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. Worth Publishers.
- Callaman, R., & Palompon, D. (2026). Development of three-dimensional resiliency theory in solving mathematical problem. *Journal of Education and Learning (EduLearn)*, 20(1), 608–621. <https://doi.org/10.11591/edulearn.v20i1.22738>
- Day, L., Siemon, D., Callingham, R., & Seah, R. (2024). Connecting the threads: the role of multiplicative thinking in algebraic, geometrical, and statistical reasoning. *Research in Mathematics Education*, 26(2), 325–347. <https://doi.org/10.1080/14794802.2024.2372365>
- de Jong, T., Lazonder, A. W., Chinn, C. A., Fischer, F., Gobert, J., Hmelo-Silver, C. E., Koedinger, K. R., Krajcik, J. S., Kyza, E. A., Linn, M. C., Pedaste, M., Scheiter, K., & Zacharia, Z. C. (2023). Let's talk evidence – The case for combining inquiry-based and direct instruction. *Educational Research Review*, 39, 100536. <https://doi.org/10.1016/j.edurev.2023.100536>
- Delima, N., Kusuma, D. A., & Paulus, E. (2024). The students' mathematics self-regulated learning and mathematics anxiety based on the use of chat GPT, music, study program, and academic achievement. *Infinity Journal*, 13(2), 349–362. <https://doi.org/10.22460/infinity.v13i2.p349-362>
- Demircioglu, T., Karakus, M., & Ucar, S. (2023). Developing students' critical thinking skills and argumentation abilities through augmented reality-based argumentation activities in science classes. *Science & Education*, 32(4), 1165–1195. <https://doi.org/10.1007/s11191-022-00369-5>

- DiNapoli, J. (2023). Distinguishing between grit, persistence, and perseverance for learning mathematics with understanding. *Education Sciences*, 13(4), 402. <https://doi.org/10.3390/educsci13040402>
- Doz, E., Cuder, A., Pellizzoni, S., Granello, F., & Passolunghi, M. C. (2024). The interplay between ego-resiliency, math anxiety and working memory in math achievement. *Psychological Research*, 88(8), 2401–2415. <https://doi.org/10.1007/s00426-024-01995-0>
- Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House.
- Dwijayanti, A. A. S. S., & Wiarta, I. W. (2024). Problem based learning using open ended questions improves students' mathematical critical thinking ability in elementary schools. *Thinking Skills and Creativity Journal*, 7(1), 167–174. <https://doi.org/10.23887/tscj.v7i1.78033>
- Emerson, R. W. (2024). Validity and reliability. *Journal of Visual Impairment & Blindness*, 118(4), 280–281. <https://doi.org/10.1177/0145482x241278447>
- Facione, P. A. (1990). *Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction*. <https://philarchive.org/archive/faccta>
- Facione, P. A., Facione, N. C., & Gittens, C. A. (2020). *What the critical thinking data tell us about our reasoning*. Insight Assessment.
- Faradillah, A., & Humaira, T. (2021). Mathematical critical thinking skills senior high school student based on mathematical resilience and domicile. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, 5(2), 1978–1991. <https://doi.org/10.31004/cendekia.v5i2.682>
- Ferreira, S. M., & Bisognin, V. (2020). Construction of mathematical and financial concepts based on realistic mathematics education. *Acta Scientiae*, 22(5), 226–253. <https://doi.org/10.17648/acta.scientiae.5925>
- Fitriani, F., Herman, T., & Fatimah, S. (2023). Considering the mathematical resilience in analyzing students' problem-solving ability through learning model experimentation. *International Journal of Instruction*, 16(1), 219–240. <https://doi.org/10.29333/iji.2023.16i113a>
- Freudenthal, H. (1973). *Mathematics as an educational task*. Springer Dordrecht. <https://doi.org/10.1007/978-94-010-2903-2>
- Gall, J. P., Gall, M. D., & Borg, W. R. (2013). *Applying educational research: How to read, do, and use research to solve problems of practice* (6th ed.). Pearson Education.
- Harianja, R., Tampubolon, T., & Manalu, L. (2023). Analysis of problem-based learning model on mathematical critical thinking skills of elementary school students. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 13(1), 101–108. <https://doi.org/10.30998/formatif.v13i1.17251>
- Hayati, R., Nurlaili, N., Zuraini, Z., Syahputra, E., Surya, E., & Abdillah, T. R. (2025). Learning revolution with integrated gamification technology and realistic mathematics education models for contextual and interesting learning. *Journal of Hunan University Natural Sciences*, 52(2), 72–83. <https://doi.org/10.55463/issn.1674-2974.52.2.7>
- Hayati, R., Syahputra, E., & Surya, E. (2026). Realistic mathematics education grounded in deliberative culture: Fostering problemsolving skills in primary education. *Scientific Culture*, 12(1), 616–628.

- İşözen, Ş., & Kaçar, A. (2026). Real-life contextualization in the geometric shapes unit of fifth grade mathematics textbooks: An analytical study. *Osmangazi Journal of Educational Research*, 12(2), 139–162. <https://doi.org/10.59409/ojer.1824447>
- Jailani, J., Retnawati, H., Rafi, I., Mahmudi, A., Arliani, E., Zulnaidi, H., Abd Hamid, H. S., & Prayitno, H. J. (2023). A phenomenological study of challenges that prospective mathematics teachers face in developing mathematical problems that require higher-order thinking skills. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(10), em2339. <https://doi.org/10.29333/ejmste/13631>
- Johar, R., Fauzan, A., Sugiman, S., Anwar, L., Sa'dijah, C., & Khairunnisak, C. (2025). Developing local instruction theory through ethnomathematics and technological-based realistic mathematics education to support students' spatial ability. *Asian Journal for Mathematics Education*, 4(4), 553–587. <https://doi.org/10.1177/27527263251383572>
- Johnston-Wilder, S., & Lee, C. (2024). *The mathematical resilience book: How everyone can progress in mathematics*. Routledge. <https://doi.org/10.4324/9781003334354>
- Khan, U. (2020). Developing critical thinking in student seafarers: An exploratory study. *Journal of Applied Learning and Teaching*, 3(1), 40–50. <https://doi.org/10.37074/jalt.2020.3.s1.15>
- Kurudirek, A., Machisi, E., & Hennig, F. (2026). Let two plus two not always equal four: A critical pedagogical exploration of mathematical certainty and context. *Eurasia Journal of Mathematics, Science and Technology Education*, 22(2), em2777. <https://doi.org/10.29333/ejmste/17831>
- Lemon, T., & Taylor, K. (2026). 21st century skills in secondary mathematics classrooms. *Mathematics Teacher: Learning and Teaching PK-12*, 119(1), 51–57. <https://doi.org/10.5951/mtlt.2025.0110>
- López-Aymes, G., Acuña, S. R., & Ordaz Villegas, G. (2020). Resilience and creativity in teenagers with high intellectual abilities. A middle school enrichment experience in vulnerable contexts. *Sustainability*, 12(18), 7670. <https://doi.org/10.3390/su12187670>
- Lubis, L. K., Lubis, A. M., Fitriani, F., Siregar, Y. A., & Jehnah, A. (2024). Analysis of students' mathematical concept understanding ability in terms of student resilience at Ban Kadeng school Thailand. *Kreano, Jurnal Matematika Kreatif-Inovatif*, 15(2), 409–422. <https://doi.org/10.15294/bc59ec96>
- Maryani, L., Riyadi, R., & Kurniawan, S. B. (2025). Comparison of problem-based learning model with direct instruction in mathematics learning towards the development of critical thinking skills. *International Journal of Current Science Research and Review*, 8(5), 2062–2069. <https://doi.org/10.47191/ijcsrr/V8-i5-13>
- Meirong, Z., & Mustafa, Z. (2025). The Chinese adaptation of the mathematical resilience scale among high school students: Validity and reliability study. *Edelweiss Applied Science and Technology*, 9(3), 864–880. <https://doi.org/10.55214/25768484.v9i3.5359>
- Méndez-Parra, C., Conde-Carmona, R. J., & Padilla-Escorcía, I. A. (2022). Characterisation of probability learning in a rural environment with the realistic mathematics education. *Acta Scientiae*, 24(4), 1–23. <https://doi.org/10.17648/acta.scientiae.6709>

- Ministry of Primary and Secondary Education. (2026). *2026 elementary school academic competency test results*. Kemendikdasmen. <https://tka.kemendikdasmen.go.id/hasiltka>
- Momdjian, L., Manegre, M., & Gutiérrez-Colón, M. (2025). A study of preservice teachers' digital competence development: Exploring the role of direct instruction, integrated practice, and modeling. *Evaluation and Program Planning*, 109, 102538. <https://doi.org/10.1016/j.evalprogplan.2025.102538>
- Muhaimin, L. H., Suryadi, D., Dasari, D., Hendriyanto, A., & Bagus Pramarta, I. N. (2026). A comparative praxeological analysis of quadrilateral and triangle concepts in Indonesian and Japanese elementary school textbooks. *Research in Comparative and International Education*, 21(1), 22–47. <https://doi.org/10.1177/17454999251411410>
- Muharram, M. R. W., Herman, T., Wahyudin, W., & Mufliva, R. (2025). Mathematical mindset, critical thinking skills, and productive struggle in learning mathematics in elementary school. In *The International Conference of Interdisciplinary Research and Studies in Mathematics: InCiReSMa2024*, (Vol. 3316, pp. 110017). <https://doi.org/10.1063/5.0290170>
- Muñoz, D., Bull, R., Khng, K. H., Ng, E. L., Poon, K., & Lee, K. (2025). Mathematics resilience in preschool and executive functions. *Learning and Instruction*, 100(1), 102197. <https://doi.org/10.1016/j.learninstruc.2025.102197>
- Murni, M., Fadhilah, F., Anzora, A., Tiara, M. P., & Yeni, M. (2026). Eco–realistic mathematics education (Eco–RME) module for students with special needs in inclusive primary schools in Aceh province. *Journal of Curriculum and Teaching*, 15(1), 92–101. <https://doi.org/10.5430/jct.v15n1p92>
- Naldi, W. (2023). *Peningkatan numerasi dan resiliensi matematis siswa kelas V sekolah dasar melalui pembelajaran realistic mathematics education (RME) [Improving numeracy and mathematical resilience of fifth-grade elementary school students through realistic mathematics education (RME) learning]*. Master's Thesis. Universitas Pendidikan Indonesia. <https://repository.upi.edu/113913/>
- Ndia, L., Salam, M., Iru, L., & Atma, N. (2025). Differentiated instruction in problem-based and direct instruction: The moderating role of mathematical disposition on students' mathematical communication skills. *Education Sciences*, 15(12), 1636. <https://doi.org/10.3390/educsci15121636>
- Nursyahidah, F., Wardono, W., Mariani, S., & Wijayanti, K. (2025). Integrating technology, Javanese ethnomathematics, and realistic mathematics education in supporting prospective mathematics teachers' numeracy skills: A learning trajectory. *Journal on Mathematics Education*, 16(2), 671–688. <https://doi.org/10.22342/jme.v16i2.pp671-688>
- OECD. (2023). *PISA 2022 results (volume I): The state of learning and equity in education*. OECD Publishing. <https://doi.org/10.1787/53f23881-en>
- Opesemowo, O. A. G., Olosunde, G. R., & Ariyo, S. O. (2025). Improving mathematics performance through after-school interventions: A gender-based analysis of low-achieving students. *Education Sciences*, 15(12), 1587. <https://doi.org/10.3390/educsci15121587>
- Palinussa, A. L., Tupamahu, P. Z., Sabandar, V. P., Makaruku, Y. H., & Sabandar, J. (2025). Realistic mathematics education: Mathematics e-modules in improving student

- learning outcomes. *Infinity Journal*, 14(1), 45–64. <https://doi.org/10.22460/infinity.v14i1.p45-64>
- Parawansa, Y., Kamid, K., & Maison, M. (2026). Analysis of students' critical thinking ability in solving mathematical problems assisted by ethnomathematics based on adversity quotient. *Journal of Mathematics Instruction, Social Research and Opinion*, 5(1), 371–387. <https://doi.org/10.58421/misro.v5i1.961>
- Pillero, J. M., Cabuquin, J. C., Dysoco, P. K., Alas, X. A., Nazal, R. M., & Manabat, M. A. A. (2026). Exploring Filipino STEM students' struggles in mathematics: Contributing factors and implications for teaching. *International Research Journal of Multidisciplinary Scope*, 7(1), 570–589. <https://doi.org/10.47857/irjms.2026.v07i01.07643>
- Polydoros, G., Galitskaya, V., Pergantis, P., Drigas, A., Antoniou, A.-S., & Beazidou, E. (2025). Innovative AI-driven approaches to mitigate math anxiety and enhance resilience among students with persistently low performance in mathematics. *Psychology International*, 7(2), 46. <https://doi.org/10.3390/psycholint7020046>
- Purnomo, Y. W., Prananto, I. W., Fitriya, Y., & Kaur, A. (2024). The role of self-regulation in the relationship between adaptability and engagement: A case of online mathematics learning for elementary school students. *Online Learning*, 28(1), 1–21. <https://doi.org/10.24059/olj.v28i1.3849>
- Rahmi, N. E. (2022). Mathematical problem-solving ability of junior high school students based on mathematical resilience in the pythagorean theorem. *Journal of Research on Mathematics Instruction (JRMI)*, 3(2), 1–10. <https://doi.org/10.33578/jrmi.v3i2.65>
- Rasyidah, R., Maisura, M., Saputra, S., Santi, Y., & Yeni, E. M. (2026). The effect of realistic mathematics education (RME) on mathematical reasoning ability and critical thinking of elementary school students in plane figures material. *Journal of Educational Sciences*, 10(2), 2488–2505.
- Samritin, S., Natsir, S. R., Manaf, A., & Sari, E. R. (2023). The effect of realistic mathematics education implementation in mathematics learning in elementary school. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, 13(1), 81–88. <https://doi.org/10.30998/formatif.v13i1.16522>
- Secadron, A. C., & Tan, D. A. (2023). Enhancing students' mathematical resilience and critical thinking skills using e-modules via process-oriented-guided-inquiry-learning approach. *American Journal of Educational Research*, 11(5), 287–296.
- Sidik, G. T., & Herman, T. (2025). The effect of the implementation of realistic mathematics education on improving critical thinking skills in solving mathematical problems. In *The International Conference of Interdisciplinary Research and Studies in Mathematics: InCiReSMa2024*, (Vol. 3316, pp. 100001). <https://doi.org/10.1063/5.0290718>
- Siswantari, S., Sabon, S. S., Listiawati, N., Wirda, Y., Zulkardi, Z., & Riyanto, B. (2025). Bridging mathematics and communication: Implementing realistic mathematics education principles for skill development. *Journal on Mathematics Education*, 16(2), 729–752. <https://doi.org/10.22342/jme.v16i2.pp729-752>
- Susandi, A. D., & Widyawati, S. (2022). Implementation of realistic mathematic education (RME) learning model in improving critical thinking skills. *Al-Jabar : Jurnal Pendidikan Matematika*, 13(2), 251–260. <https://doi.org/10.24042/ajpm.v13i2.14996>

- Susanti, P., Utomo, S., & Sumaji, S. (2022). The effectiveness of realistic mathematics education learning approach on critical thinking skills of elementary school students. *ANARGYA: Jurnal Ilmiah Pendidikan Matematika*, 5(2), 197–205. <https://doi.org/10.24176/anargya.v5i2.8308>
- Sutama, S., Fuadi, D., Narimo, S., Hafida, S. H. N., Novitasari, M., Anif, S., Prayitno, H. J., Sunanih, S., & Adnan, M. (2022). Collaborative mathematics learning management: Critical thinking skills in problem solving. *International Journal of Evaluation and Research in Education (IJERE)*, 11(3), 1015–1027. <https://doi.org/10.11591/ijere.v11i3.22193>
- Sutarni, S., Sutama, S., Prayitno, H. J., Sutopo, A., & Laksmiwati, P. A. (2024). The development of realistic mathematics education-based student worksheets to enhance higher-order thinking skills and mathematical ability. *Infinity Journal*, 13(2), 285–300. <https://doi.org/10.22460/infinity.v13i2.p285-300>
- Syamsulrizal, S., Khabibah, S., Lukito, A., & Madzkiyah, A. F. (2025). Students' critical thinking dispositions in view of cognitive styles: Exhibiting confidence in reasoning and inquisitive. *Perspectives of Science and Education*, 73(1), 583–594. <https://doi.org/10.32744/pse.2025.1.37>
- Taja-on, E. P., Dajero, B. K. C., & Barete, M. G. (2025). Mathematics and modern society: A delphi study exploring mathematics education towards Education 4.0. *Educational Point*, 2(1), e120. <https://doi.org/10.71176/edup/16534>
- Umar, U., Kaharuddin, A., Fauzi, A., Widodo, A., Radiusman, R., & Erfan, M. (2020). A comparative study on critical thinking of mathematical problem solving using problem based learning and direct intruction. In *Proceedings of the 1st Annual Conference on Education and Social Sciences (ACCESS 2019)*, (pp. 314–316). <https://doi.org/10.2991/assehr.k.200827.079>
- Van den Heuvel-Panhuizen, M., & Drijvers, P. (2020). Realistic mathematics education. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 713–717). Springer International Publishing. https://doi.org/10.1007/978-3-030-15789-0_170
- van Viersen, S., Psyridou, M., & Torppa, M. (2026). General introduction to the special issue on resilience in learning. *Learning and Instruction*, 101(1), 102254. <https://doi.org/10.1016/j.learninstruc.2025.102254>
- Ventistas, G., Ventista, O. M., & Tsani, P. (2025). The impact of realistic mathematics education on secondary school students' problem-solving skills: a comparative evaluation study. *Research in Mathematics Education*, 27(3), 437–461. <https://doi.org/10.1080/14794802.2024.2306633>
- Wardana, A., Sukestiyarno, Y. L., Wardono, W., & Suyitno, A. (2024). Analysis of high school students' critical thinking ability in solving mathematical problems with independence problem-based learning (IPBL) model: A case study on middle class students. *Educational Administration: Theory and Practice*, 30(3), 7137–7147. <https://doi.org/10.53555/kuey.v30i4.1523>
- Wibowo, S., Wangid, M. N., & Firdaus, F. M. (2025). The relevance of Vygotsky's constructivism learning theory with the differentiated learning primary schools. *Journal of Education and Learning (EduLearn)*, 19(1), 431–440. <https://doi.org/10.11591/edulearn.v19i1.21197>

- Wu, T.-T., Silitonga, L. M., Dharmawan, B., & Murti, A. T. (2024). Empowering students to thrive: The role of CT and self-efficacy in building academic resilience. *Journal of Educational Computing Research*, 62(3), 596–625. <https://doi.org/10.1177/07356331231225468>
- Xenofontos, C., & Mouroutsou, S. (2023). Resilience in mathematics education research: A systematic review of empirical studies. *Scandinavian Journal of Educational Research*, 67(7), 1041–1055. <https://doi.org/10.1080/00313831.2022.2115132>
- Yohannes, A., & Chen, H.-L. (2024). The effect of flipped realistic mathematics education on students' achievement, mathematics self-efficacy and critical thinking tendency. *Education and Information Technologies*, 29(13), 16177–16203. <https://doi.org/10.1007/s10639-024-12502-8>
- Zanganeh, A., Haj Hosseini, M., & Hosseini, S. (2025). The role of mathematical self-efficacy in the relationship between mathematical resilience and academic achievement in mathematics among humanities students. *Iranian Journal of Applied Educational Research*, 1(1), 1–9.