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The effect of GASING with teaching at the right level on third-grade students' critical thinking in addition

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ABSTRACT

Critical thinking remains a fundamental competency that has yet to be optimally developed in elementary mathematics education, particularly when instructional approaches fail to account for differences in students' cognitive readiness. This study aims to examine the effect of integrating the GASING method (Gampang, aSyIk, nyeNGkan) with Teaching at the Right Level (TaRL) on the critical thinking skills of third-grade elementary school students in addition learning. A quasi-experimental design with a non-equivalent control group was employed, involving 88 students divided into a control group ($n = 43$), which received GASING instruction, and an experimental group ($n = 45$), which received instruction integrating GASING and TaRL. Critical thinking skills were assessed based on students' abilities to analyze quantitative relationships, justify mathematical reasoning, and evaluate problem-solving strategies using an eight-item analytical rubric with a maximum score of 24. Before the intervention, both groups had relatively comparable baseline scores, as indicated by the Welch's t-test ($t(78.85) = 1.445$; $p = 0.152$). Improvements in critical thinking skills (Gain_CT) were analyzed using an independent-samples t-test after testing for normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test. The results showed that the experimental group achieved a significantly higher mean improvement than the control group ($M = 44.60$ vs. $M = 24.65$; $t(86) = -4.640$; $p < 0.001$; Cohen's $d = 0.99$), indicating a large effect size. These findings suggest that structured, reasoning-oriented instruction combined with ability-based cognitive differentiation can support the development of critical thinking skills among students with diverse ability levels. This study provides empirical evidence of the importance of diagnostic assessment as a foundation for designing elementary mathematics instruction and highlights the potential of adaptive learning in developing higher-order thinking skills.



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Introduction

Critical thinking skills play an important role in learning mathematics in elementary school because they help students process information, understand the relationships between concepts, and choose problem-solving strategies logically and in a structured manner (Rahmawati et al., 2024; Walidainismawati et al., 2021). In the

context of mathematics learning, this ability allows students to gain a deeper understanding of concepts, especially when solving contextual problems that demand mathematical analysis, evaluation, and reasoning skills (Narváez et al., 2026). In addition, critical thinking skills also support the improvement of mathematical literacy because students can relate mathematical concepts to real situations and make rational decisions (Waluya et al., 2024). Strengthening critical thinking skills is also in line with the needs of 21st century skills, because these skills can shape students into reflective, creative, and problem-solving individuals through the application of innovative learning approaches such as Realistic Mathematics Education and problem-based learning (Aktoprak & Hursen, 2022; Cahyaningsih & Nahdi, 2021).

Elementary school students face various obstacles in developing mathematical critical thinking skills on summation materials, especially when understanding story problems and interpreting the relationships between information contained in math problems (Muharram et al., 2025; Walidainismawati et al., 2021). In addition, students often have difficulty in representing problems into mathematical forms, such as converting verbal information into appropriate operations or summation equations (Sidik et al., 2025). Another obstacle appears to be the low understanding of the basic concept of summation and the inability of students to connect interrelated mathematical concepts, so they easily experience confusion when facing problems with a higher level of complexity (Kharisudin & Ardiansyah, 2021). In the process of critical thinking, students are also not fully able to clarify, evaluate, infuse, or re-check the answers obtained because they tend to accept the first answer without conducting an in-depth analysis (Rahmawati et al., 2024). In addition, the lack of contextual exercises that are close to daily life cause students to have difficulty relating the concept of summation to real situations, so that mathematical problem-solving skills have not been developed optimally (Cahyaningsih & Nahdi, 2021). Another factor that hinders the development of critical thinking skills of elementary school students is the limited time, learning resources, and readiness of teachers to integrate critical thinking learning into mathematics learning (Trisnani et al., 2024).

The GASING method (GAmpang, aSyIk, menyenaNGkan) contributes to developing the reasoning and critical thinking strategies of elementary school students through learning that emphasizes the understanding of concepts gradually and meaningfully, so that students are able to build mathematical logic from the basic stage through the exploration of patterns and relationships between concepts (Pratiwi et al., 2021). In addition, the GASING method has a significant role in improving the critical thinking skills of elementary school students because the learning process is designed in a systematic, gradual, concrete, and fun manner so as to encourage students to be more active in understanding mathematical concepts rather than simply memorizing procedures or formulas. This approach emphasizes exploratory activities, thinking exercises, and student-centered learning, so as to be able to develop the ability to analyze, reason, and solve problems logically and rationally (Taufik, 2024). In addition to being oriented towards mastering concepts, the GASING method also encourages students to evaluate information, express opinions, and find solutions to contextual problems through an interactive and reflective learning process (Rahangmetan et al., 2026).

The Teaching at the Right Level (TaRL) approach is considered effective in supporting the development of students' critical thinking, analysis, and reasoning skills because the learning process is adjusted to the level of ability and learning needs of each student, so that learning becomes more directed and meaningful. The application of the TaRL-based Differentiated Science Inquiry model has been proven to be able to improve students' critical thinking skills through learning activities that encourage concept exploration, problem analysis, and the development of science process skills gradually in accordance with students' learning readiness (Sari et al., 2025). In addition, the combination of the TaRL approach with Problem-Based Learning (PBL) also makes a positive contribution to improving students' reasoning and problem-solving skills because students are actively involved in solving contextual problems related to daily life (Mustafa et al., 2024). The integration of educational technology in the TaRL approach also supports students' analytical skills through the use of digital media and data-based learning that is more adaptive and interactive (Machkour et al., 2026). In addition, the TaRL approach has been proven to help students understand numerical concepts more logically and systematically, so as to reduce errors in understanding concepts and improve students' mathematical reasoning skills (Lamaizi et al., 2024).

This research is based on two complementary theoretical foundations, namely *Cognitive Load Theory* (CLT) and *Zone of Proximal Development* (ZPD). CLT developed by Sweller (1988) states that the working memory capacity of humans is limited, so cognitive load that exceeds this capacity will hinder information processing and the formation of meaningful understanding. In the context of math learning, this means that tasks that go too far beyond the student's actual abilities will divert cognitive resources from high-level thinking activities such as analysis, justification, and evaluation to mere superficial procedural processing. Therefore, an effective

instructional design must be able to adapt the complexity of the task to the cognitive capacity of each student so that the available cognitive space can be optimized to support critical thinking.

Meanwhile, the concept of ZPD formulated by Vygotsky defines the distance between actual abilities that students can achieve independently and potential abilities that can be achieved through mentorship or collaboration. Optimal learning occurs when students are faced with challenges that are right at the upper limit of their actual abilities, accompanied by adaptively differentiated *scaffolding*. This condition cannot be realized in a uniform instructional approach, but rather requires a differentiation mechanism that is able to recognize and respond to the diversity of individual students' cognitive readiness.

Based on these two theoretical frameworks, this study positions the GASING method as an instructional approach that inherently supports the reduction of extrinsic cognitive burden through a gradual and concrete sequencing of learning from the exploration of real objects to symbolic abstraction so that students can build mathematical reasoning in a structured manner without experiencing cognitive overload. On the other hand, the *Teaching at the Right Level* (TaRL) approach acts as a mechanism for operationalizing ZPD on a classroom scale: through ability-based grouping and adaptive task differentiation, TaRL ensures that each student receives challenges and support that corresponds to their respective proximal development zones. The synergy between GASING and TaRL thus theoretically creates optimal learning conditions for the development of critical thinking, because students are not only exposed to a structured reasoning process, but also get cognitive stimulation at the right level according to their learning readiness. This framework is the basis for the research hypothesis that the integration of GASING-TaRL will result in a greater increase in critical thinking skills compared to the use of GASING without ability-based differentiation.

The integration of GASING and Teaching at the Right Level (TaRL) methods theoretically has strong potential, as it combines reasoning-oriented learning with cognitive support tailored to the student's ability level. This combination allows students to engage more optimally in the thinking process, thus potentially improving critical thinking skills in the context of mathematics. Although this study uses arithmetic material, the main focus does not lie on mastering the addition operation alone, but rather on how the material is used as a context to develop students' critical thinking processes, which include the ability to analyze, provide justification, and evaluate solutions. Therefore, this study aims to empirically examine whether the integration of the GASING method with the Teaching at the Right Level (TaRL) approach can significantly improve the critical thinking skills of grade III elementary school students on summation materials, compared to the use of the GASING method without the integration of TaRL. In particular, this study seeks to: (1) analyze the difference in critical thinking ability improvement between the group that received TaRL's integrated GASING learning and the group that only received GASING learning; (2) measure the magnitude of the practical effect of the difference using Cohen's *d*; and (3) provide empirical evidence that supports the urgency of implementing competency-based learning differentiation as an effective instructional strategy in the development of mathematical critical thinking at the elementary school level. Thus, this research is expected to make a theoretical contribution to the development of reasoning-based adaptive learning frameworks, as well as provide practical implications for teachers in designing mathematics learning that is more responsive to the diversity of students' cognitive abilities.

Although previous studies have examined the effectiveness of the GASING method in basic mathematics learning (Herlambang et al., 2022; Pratiwi et al., 2021; Taufik, 2024; Rahangmetan et al., 2026) and a number of other studies have demonstrated the potential of the TaRL approach in improving students' cognitive abilities (Mustafa et al., 2024; Sari et al., 2025; Lamaizi et al., 2024), two critical gaps in the existing literature have not been adequately addressed. First, no studies have explicitly examined the integration of the two approaches GASING and TaRL as a mutually reinforcing instructional design unit. Existing research tends to test each approach separately or combine TaRL with a different framework (such as PBL), without exploring its specific synergies with gradual reasoning-based methods such as GASING. Second, research on the development of critical thinking at the elementary level (grades I-III) is still very limited compared to the high grades, even though the foundation of critical thinking is most critically built in the early stages of cognitive development. In particular, there has been no study that places summation material as a pedagogical context to develop critical thinking through the combination of GASING-TaRL in grade III students. This study fills the gap directly by adopting a quasi-experimental design that allows causal comparisons between GASING alone and TaRL-integrated GASING, as well as operationalizing critical thinking in a multidimensional manner through analytical rubric instruments that include the ability to analyze, justify, and evaluate solution strategies. Thus, this research makes an original empirical contribution while offering a concrete instructional model that can be adopted by teachers in the context of basic education in Indonesia and other developing countries that face similar challenges in managing the diversity of students' cognitive abilities.

Method

Research Design

This study used a quasi-experimental design with a *non-equivalent control group*. The *pretest–posttest* design is applied to measure the increase (*gain score*) of students' critical thinking skills.

Participants

A total of 88 elementary school third grade students participated in this study. Participants came from six classes spread across six different elementary schools in the Obaa District area, Mappi Regency, South Papua Province. The study involved two groups, namely a control group consisting of 43 students and an experimental group consisting of 45 students. The selection of participants is carried out based on the classes that have been determined by the school, so that each class represents the learning conditions that take place naturally in each school.

Instruments

Critical thinking instruments are given in the form of *pretest* and *posttest* to measure students' critical thinking skills in solving mathematical problems, especially in addition materials. This instrument is designed to assess students' ability to reason, analyze, and solve problems through a high-level thinking process. The instrument consists of eight questions that include four indicators of critical thinking, with each item being assessed using an analytical rubric on a scale of 0–3 (maximum score per item = 3; maximum total score = 24). In particular, instruments require students to: a. analyze the relationship between quantities, b. explain and justify their reasoning, c. compare various solution strategies, and. evaluate the correctness of the answers obtained.

Thus, the instrument emphasizes more on the measurement of high-level thinking processes rather than just procedural accuracy. Improvement score (*Gain_CT*) is calculated as the difference between *posttest* and *pretest* scores. The use of *raw gain scores* was consciously selected by considering a number of psychometric arguments. First, both groups showed an average pretest score that was well below the instrument's maximum score (control: $M = 14.69$ out of a maximum of 24; experiment: $M = 11.37$ out of a maximum of 24), so there was still considerable room for improvement and the risk of a *significant ceiling effect* could be empirically ruled out. Second, the equivalence of the initial ability of the two groups was confirmed through Welch's t-test ($t(78.85) = 1.445$; $p = .152$), so that the threat of *regression to the mean* which is differential between groups is considered minimal. Third, the *raw gain score* maintains the original unit of measurement of the instrument so that the substantive interpretation of the amount of increase is more direct and transparent. Nonetheless, the study acknowledges that alternatives such as *normalized gain* ($g = (\text{posttest} - \text{pretest}) / (\text{maximum score} - \text{pretest})$) have the potential to improve comparability between individuals with different starting points, and are recommended to be considered in replication studies with a more heterogeneous range of initial abilities.

The empirical quality of the instruments was verified through tests of the difficulty level of the questions (TKS) and differentiating power (DP) carried out on 50 test respondents. The results of the analysis showed that the TKS scores of the eighth question item ranged from 0.31 to 0.57, all of which were in the "adequate" category, so that they were assessed according to the cognitive abilities of grade III elementary school students. The DP value ranges from 0.25 to 0.59; four question items (Questions 1–4) were categorized as "very good", three question items (Questions 5–7) were categorized as "good", and one question item (Question 8) was categorized as "adequate". Based on these results, all eight questions were declared feasible and maintained for use in the research. A summary of the results of the quality analysis of the question items is presented in Table 1. Given that the instrument is based on an analytical rubric that involves subjective assessment, inter-rater reliability is verified using the Intraclass Correlation Coefficient (ICC) model two-way mixed, absolute agreement. The assessment is carried out independently by two trained raters on all student answer sheets. The results of the ICC calculation showed very high values in all data groups: ICC = 0.988 in the control group ($n = 43$), ICC = 0.988 in the experimental group ($n = 45$), and ICC = 0.990 in the combined data ($N = 88$). Based on the criteria of Koo and Mae (2016), the three ICC values are in the "excellent" category ($ICC \geq 0.90$), which indicates a very high level of consistency of assessment between assessors and supports the reliability of the measurement data in this study. A summary of the results of the inter-rater reliability test is presented in Table 1.

Table 1. Test Results of the Difficulty Level and Differentiating Power of Critical Thinking Instruments

Question Item	TKS	Category: TKS	DP	Category DP	Remarks
1	0,573	Enough	0,505	Excellent	Digunakan
2	0,513	Enough	0,588	Excellent	Digunakan
3	0,320	Enough	0,458	Excellent	Digunakan
4	0,313	Enough	0,468	Excellent	Digunakan

Question Item	TKS	Category: TKS	DP	Category DP	Remarks
5	0,373	Enough	0,325	Good	Digunakan
6	0,347	Enough	0,365	Good	Digunakan
7	0,493	Enough	0,329	Good	Digunakan
8	0,473	Enough	0,252	Enough	Digunakan

Pretest data showed that the initial ability of both groups was at an equal level before the intervention was implemented. The control group ($n = 43$) obtained an average *pretest* score of $M = 14.69$ ($SD = 12.04$), while the experimental group ($n = 45$) obtained an average score of $M = 11.37$ ($SD = 9.26$). The Levene test showed that the variance of the two groups differed significantly ($F = 4.509$; $p = 0.037$), so the group equivalence test was performed using *Welch's t-test (equal variances not assumed)*. The test results showed no significant difference between the two groups ($t(78.85) = 1.445$; $p = 0.152$), so it can be concluded that both groups had comparable initial critical thinking abilities before treatment was given.

Intervention

This study involved two treatment conditions that were carried out for two weeks with a frequency of two meetings per week (a total of four learning sessions, 70 minutes each per session). Outside of the learning session, one additional meeting is allocated for the implementation of the pretest before the intervention begins, and one additional meeting for the implementation of the posttest after the intervention is completed. All learning sessions are taught by classroom teachers who have received training on the procedures of both methods before the intervention begins, to ensure uniformity of implementation.

The control group received learning using the GASING method (*Gampang, aSyIk, menendNGkan*) which emphasized the process of solving problems in a structured manner. Learning begins with the exploration of numerical patterns using concrete objects (grains, color pieces), continues with semi-concrete representations through numbers pictures and diagrams, and ends with symbolic abstraction on formal mathematical notation. In each session, students are given contextual problems that require them to identify important information, choose strategies, and explain the solution steps orally or in writing. The teacher acts as a facilitator who guides the student's reasoning process through *guided questioning*, regardless of the level of ability of students in class grouping.

Meanwhile, the experimental group obtained GASING learning integrated with TaRL (*Teaching at the Right Level*), where students were grouped based on cognitive readiness and engaged in reasoning activities according to their ability level. The grouping was conducted based on the results of a diagnostic assessment given one week before the intervention began, resulting in three groups of ability: high ($n = 14$), moderate ($n = 20$), and low ($n = 11$). At the beginning of each session, teachers carry out a short formative assessment (5 minutes) to verify students' learning readiness and adjust the complexity of the assigned tasks. Students at the low ability level received scaffolding more intensively with the use of concrete props and hands-on mentoring, students at the medium level were given gradual problem-solving challenges, while students at the high level were encouraged to explore various alternative strategies, provide justification, and evaluate the efficiency of completion. All ability groups use the same GASING material as the foundation of learning, but with the complexity of the problem and the form of customized support. The grouping process is flexible and can be reviewed every two sessions based on student learning progress.

Teacher Training and Fidelity of Implementation

The teachers involved in this study did not receive any special retraining before the intervention was implemented. This is because all teachers have participated in intensive training on the GASING method for 14 days in the previous program, which includes basic mathematics operation learning concepts and strategies, including addition, subtraction, multiplication, and division. In addition, teachers have experience in applying the GASING method in the classroom so that they are considered to have mastered the approach well.

Before the implementation of the research, the researcher gave a brief briefing to teachers in the experimental class about learning steps based on *the Teaching at the Right Level* (TaRL) approach, including the procedure for grouping students based on their abilities and the flow of learning activities. To maintain consistency in the implementation of interventions, the researcher conducted periodic classroom observations using observation sheets and reflective discussions with teachers after each learning session. This mechanism functions as a *fidelity check* to ensure that intervention procedures are implemented consistently in accordance with the research design.

Data Analysis

Data were analyzed using descriptive statistics, Shapiro-Wilk normality test, and *independent samples t-test* with a significance level of $\alpha = 0.05$. Before the t-test is implemented, the assumption of variance homogeneity is verified using the Levene test (*Levene's Test for Equality of Variances*). The results of the Levene test on the increase score data (Gain_CT) showed that the variance of the two groups did not differ significantly ($F = 0.624$; $p = 0.432$ different from the Levene test on the pretest data which yielded $p = 0.037$), so that the homogeneity of variance assumption was fulfilled for the main inferential analysis and the use of the t-test assuming equal variances is declared to be accurate. Thus, the overall data analysis procedure includes four sequential stages: (1) descriptive statistics to describe the distribution of *gain* scores of the two groups; (2) Shapiro-Wilk normality test to verify data distribution; (3) the Levene test to check the homogeneity of variance between groups; and (4) *the Independent Samples T-Test* to test the difference in the mean improvement score (*Gain_CT*) between the control group and the experimental group inferentially. All analyses were performed using SPSS software version 26.0.

Results and Discussions

Statistics Descriptive

Table 2. Descriptive Statistics Critical Thinking Ability Gain Score

Group	N	Mean	Hours of deviation	Minimum	Maximum
GASING (Control)	43	24.65	19.13	-16.00	58.00
GASING + TaRL (Experimental)	45	44.60	21.10	-8.00	92.00

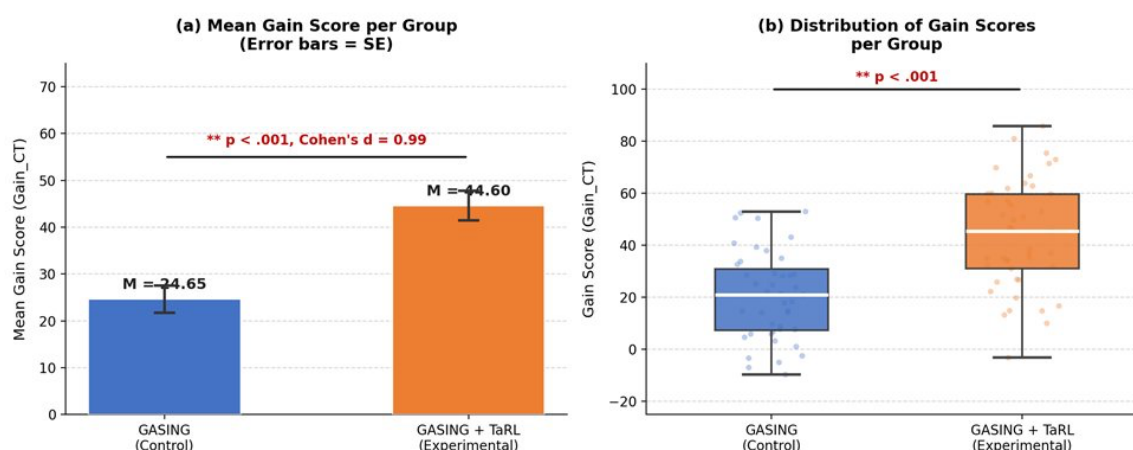


Figure 1. Comparison of critical thinking gain scores (Gain_CT) between the GASING (Control) group and GASING+TaRL (Experimental) group.

Note. Panel (a) presents mean scores with standard error bars; panel (b) shows score distributions as box plots with individual data points overlaid. $** p < .001$; Cohen's $d = 0.99$.

Table 2 presents descriptive statistics of critical thinking ability gain scores (Gain_CT) from both groups. The experimental group (GASING + TaRL) obtained an average gain score of 44.60 ($SD = 21.10$), while the control group (GASING) obtained an average of 24.65 ($SD = 19.13$). The mean difference between groups of 19.95 points showed that the experimental group experienced a much greater improvement in critical thinking skills than the control group. The gain score range in the experimental group (-8.00 to 92.00) was wider than in the control group (-16.00 to 58.00), indicating a more diverse variation in individual responses in the experimental group, but with a more maintained lower limit. The existence of negative gain scores in both groups reflects the presence of a small number of students who experience a decrease in scores from pretest to posttest, a phenomenon that will be discussed further in the discussion section. Overall, this descriptive picture provides a strong early indication that the integration of TaRL into the GASING method has a positive impact on improving students' critical thinking skills.

Normality Test**Table 3.** Data Normality Test Results

Group	Statistic	df	Sig.
Control	.950	43	.058
Experimental	.957	45	.091

Based on the results of the Shapiro-Wilk normality test in the table above, the control group data obtained a statistical value of 0.950 with a degree of freedom (df) = 43 and a significance value of 0.058, while the data of the experimental group obtained a statistical value of 0.957 with a degree of freedom (df) = 45 and a significance value of 0.091. Both groups produce a significance value greater than 0.05, so H_0 is accepted. This shows that the data in both groups are normally distributed and meet one of the basic assumptions to proceed to parametric statistical tests.

Uji Independent Samples T-Test**Table 4.** Independent Samples T-Test Results

Variable	t	df	Sig. (2-tailed)	Mean Difference	Cohen's d
Gain_CT	-4.640	86	.000	-19.949	0.99

The results of the *independent samples t-test* in Table 4 show that there was a significant difference in the critical thinking ability gain score (Gain_CT) between the experimental group and the control group ($t(86) = -4.640$; $p < 0.001$; *Mean Difference* = -19.949). A negative t-value reflects that the average gain score of the control group is used as a comparative reference, and the direction of the difference indicates the advantage of the experimental group. With a significance value well below the threshold of $\alpha = 0.05$, H_0 was rejected and it was concluded that the integration of the GASING method with TaRL significantly improved students' critical thinking skills compared to the use of the GASING method alone. Next, to measure the practical magnitude of the difference, the *effect size* is calculated using Cohen's *d*. Calculations using the *pooled standard deviation* formula yielded $SD_{pooled} = 20.16$, resulting in Cohen's value $d = 0.99$. Based on the Cohen (1988) convention, this value falls into the category of *large effect* ($d \geq 0.80$), which indicates that the differences between groups are not only statistically significant, but also have substantial practical significance. Overall, the results of this inferential test provide strong evidence that the integration of GASING with TaRL results in a greater and more meaningful increase in critical thinking skills in practice compared to the use of the GASING method without ability-based differentiation.

Inter-Rater Reliability**Table 5.** Inter-Appraiser Reliability Test (ICC) Results

Group	Number of Participants	ICC Value	Interpretation
Control Group	43	0.988	Excellent
Experimental Group	45	0.988	Excellent
Combined Data	88	0.990	Excellent

Table 5 presents the results of the inter-assessor reliability test using the Intraclass Correlation Coefficient (ICC) model two-way mixed, absolute agreement. The assessment of all student answer sheets ($N = 88$) was carried out independently by two trained raters. The results showed that the ICC value was very high in all data groups: the control group obtained an ICC = 0.988 ($n = 43$), the experimental group obtained an ICC = 0.988 ($n = 45$), and the combined data obtained an ICC = 0.990 ($N = 88$). Based on the criteria of Koo and Mae (2016), the three scores are included in the category of "excellent" ($ICC \geq 0.90$), which indicates a very high level of consistency and agreement between assessors. These findings strengthen the reliability of the critical thinking measurement data in this study and show that the scores obtained are not significantly affected by differences in perception between assessors, so that the validity of the measurement of the analytical rubric instrument can be accounted for methodologically.

Critical thinking skills are one of the core competencies required in 21st century mathematics learning, but their development at the elementary school level still faces persistent challenges. International studies have consistently shown that learning practices centered on the transmission of procedures and memorization of answers have not been able to build students' reasoning and evaluation capacity optimally (Aktoprak & Hursen,

2022; Cahyaningsih & Nahdi, 2021). In Indonesia, this condition is exacerbated by the gap between the very diverse levels of students' cognitive abilities in a classroom and uniform instructional approaches, so that most students do not get critical thinking stimulation at a level that matches their learning readiness (Muharram et al., 2025; Trisnani et al., 2024). This context underlies the urgency of this research: efforts to respond to these gaps through the integration of the GASING method that is oriented towards gradual reasoning with the Teaching at the Right Level (TaRL) approach that allows for competency-based instructional differentiation. The resulting findings are not only relevant to answering specific research questions, but also contribute to a broader debate about how adaptive learning design can open up equal access to the development of high-level thinking skills for all students, regardless of their initial abilities.

The findings of this study show that the experimental group that received TaRL-integrated GASING learning obtained an average critical thinking improvement score (Gain_CT) of 44.60, significantly higher than the control group that only received GASING ($M = 24.65$; $t(86) = -4.640$; $p < 0.001$; Cohen's $d = 0.99$). This relatively large magnitude of the effect indicates that the differences between groups are not only statistically significant, but also have substantial practical significance in the context of mathematics learning in elementary school grades. These findings are in line with theoretical predictions built from the framework *Cognitive Load Theory* (CLT) and *Perspective Zone of Proximal Development* (ZPD). Within the CLT framework, the integration of TaRL into GASING learning functionally reduces the extrinsic cognitive load as the assigned tasks are tailored to the processing capacity of each student, so that working memory resources can be allocated more efficiently for higher-level thinking activities such as analysis, justification, and evaluation (Evans & Martin, 2023). Meanwhile, from a ZPD perspective, ability-based grouping in TaRL allows each student to interact with a mathematical challenge that is just above the upper limit of his or her actual ability, with support *scaffolding* that are adaptively differentiated (Kantar et al., 2020; Ponmani & Geetha, 2022; Ramdhani et al., 2025). This condition synergistically creates an optimal space for the development of critical thinking skills, because students are not burdened cognitively, but are also not in a comfort zone that hinders the development of their reasoning.

The improvement of critical thinking skills in the experimental group was specifically reflected in the three dimensions that were the focus of this research instrument: the ability to analyze mathematical relationships, provide justifications for reasoning, and evaluate solution strategies. These three dimensions develop through the pedagogical mechanisms inherent in the GASING method, namely the exploration of numerical patterns through concrete objects, semi-concrete representations, and symbolic abstraction that are carried out gradually. This approach encourages students to not only find answers, but also to understand why a strategy works and how the relationships between concepts are formed, which is at the core of the analytical and evaluative thinking process (Pratiwi et al., 2021). The active involvement of students in explaining the completion steps during the learning session also results in a cognitive elaboration process that strengthens the structure of their mathematical knowledge in more depth. TaRL integration at this stage has a critical role: by ensuring that the problems given are appropriate to the cognitive level of each group, TaRL prevents cognitive frustration in low-ability students while maintaining intellectual challenges for high-ability students, so that critical thinking processes can develop inclusively across the entire spectrum of abilities (Banerjee et al., 2016; Kaffenberger, 2021).

Although the aggregate findings show significant improvements, the descriptive data reveal individual variations that need to be critically examined. The minimum score of the Gain_CT in the control group was -16.00 , while the experimental group recorded a minimum score of -8.00 . Existence *negative gains* This indicates that a small percentage of students experience a decrease in critical thinking scores from pretest to posttest, and this phenomenon requires careful interpretation. From perspective *Cognitive Load Theory* (CLT), *negative gains* can occur when students experience cognitive overload (*cognitive overload*) due to the demands of critical thinking that exceed their working memory capacity, especially when the assignment or question format given has a high complexity, thus reducing students' ability to understand information and solve problems effectively (Patel & Alismail, 2024; Rebello et al., 2024). In addition, situational factors such as exam anxiety (*test anxiety*), health conditions, or motivational instability on the day of the posttest can also contribute to performance that does not reflect the actual ability of the student (Zhang et al., 2020). It is important to note that the proportion of students with *negative gains* greater was found in the control group (minimum value -16.00) than in the experimental group (-8.00), indicating that TaRL integration provides relative protection against

performance decline, particularly for students at risk of cognitive overload. This is consistent with the argument that ability-based differentiation in TaRL acts as a mechanism *protective buffer*. Because it is able to reduce learning gaps, increase student motivation and involvement, and provide adaptive learning support according to students' ability levels so that it can protect students from the risk of continuous academic lag (Hartono et al., 2025; Lamaizi et al., 2024; Machkour et al., 2026; Mustafa et al., 2024).

Although the findings of this study provide strong empirical evidence, some internal validity threats need to be recognized and critically considered in interpreting these results. First, selection bias is an inherent threat to quasi-experimental design with non-equivalent control groups. The placement of students into control groups and experiments was not done randomly but on the basis of naturally formed classes, so it cannot be completely ruled out that differences in initial characteristics between classes beyond pretest scores contributed to differences in outcomes (Rafiki et al. 2025; Rezeki et al. 2026). Nonetheless, this risk has been mitigated through initial ability equity verification using Welch's t-test which confirms no significant difference in pretest scores ($t(78.85) = 1.445$; $p = .152$), as well as through the selection of the same school for both groups to minimize the influence of contextual variables such as the quality of school infrastructure and the socio-economic background of students. Second, the historical effect needs to be considered, i.e. the likelihood that learning events or experiences outside of the intervention session such as private tutoring, home-learning activities, or media influences had different impacts on the two groups over the study period. This threat is difficult to fully control in a naturalistic setting, but the impact is expected to be minimal given the relatively short duration of the intervention (two weeks) and the two groups being in the same school and community context. Third, the maturation effect describes the risk that the observed increase in critical thinking is partly a result of the student's natural cognitive development during the study period, rather than solely as a result of the intervention. This threat is most relevant in long-term research; Given that the intervention lasted only four sessions in two weeks, the contribution of maturation to differences between groups was considered insubstantial. Fourth, instrumentation threats need to be observed: although the instrument has been empirically verified through TKS and differentiation tests, subjective analytical rubric assessments have the potential to open up the possibility of inter-rater variability. This threat has been explicitly addressed in this study through the calculation of the Intraclass Correlation Coefficient (ICC) carried out on all student answer sheets by two independent raters. The ICC results showed a value that was classified as "excellent" for all data groups (ICC = 0.988 for the control group; ICC = 0.988 for the experimental group; ICC = 0.990 for the combined data), based on the criteria of Koo and Mae (2016). These findings confirm that the level of consistency of assessment between assessors is very high, so measurement variability due to assessor subjectivity can be ruled out as a meaningful threat to data validity. Despite these limitations, the convergence between the statistical significance ($p < .001$) and the large magnitude of the effect (Cohen's $d = 0.99$) provides confidence that the findings of this study reflect the real impact of the treatment given, rather than just a methodological artifact.

Overall, the findings of this study strengthen and expand the existing literature on the effectiveness of adaptive learning approaches in the development of mathematical critical thinking. This study provides empirical evidence that the competitive advantage of the experimental group is not solely due to exposure to the GASING method, but specifically by the synergy between the reasoning-oriented approach and the cognitive differentiation structure offered by TaRL. Active involvement of students in explaining, analyzing, and evaluating thought processes through differentiated learning designs such as *TaRL* contributes to the formation of a reflective and logical mindset that is the basis of critical thinking skills, as learning is adjusted to the level of cognitive readiness of students and encourages them to reason, reflect, and make decisions in more depth (Bekbayeva et al., 2022; Christinove & Rosyida, 2022; Mustafa et al., 2024; Ramlawati et al., 2025). From the perspective of educational practice, these findings confirm that the application of competency-based diagnostic assessments plays an important role as the basis for adaptive and effective instructional design in elementary schools because it allows teachers to more accurately identify students' learning needs, misconceptions, and skill profiles, while learning interventions oriented to reasoning, analysis, and problem-solving have been shown to have more potential in developing skills. high-level thinking versus approaches that only emphasize procedural precision (Alfageh et al., 2024; Ashirimbetova et al., 2024; Drenoyianni & Kourtis, 2024; Ismail et al., 2024; Thompson & Clark, 2024; Wilkins, 2025).

Although the sample of this study was sourced from a remote sub-district in Mappi Regency, South Papua an area characterized by limited educational infrastructure, high heterogeneity of cognitive abilities among students, and lack of access to digital learning resources these contextual characteristics make these findings

potentially broadly relevant to international readers. The conditions faced in Mappi are not unique, but reflect structural challenges common in rural and disadvantaged areas in developing countries: wide skills gaps in a single classroom, limited number of trained teachers, and pressure to improve learning outcomes without significant resource additions. In this context, the core principle of the research intervention design the use of competency-based diagnostic assessments as a foothold for instructional differentiation, combined with a structured learning approach in stages is a mechanism that is essentially not tied to a specific cultural context or method. The *Teaching at the Right Level* (TaRL) approach itself has shown its effectiveness in a wide variety of contexts: from primary schools in rural India to the Pratham program that pioneered this approach (Banerjee et al., 2016; Kaffenberger, 2021), to secondary schools in Morocco in the context of learning numerical sequence mathematics (Lamaizi et al., 2024), and schools in Kasablanka with digital technology integration (Machkour et al., 2026). This cross-contextual convergence pattern indicates that the core mechanisms of TaRL actual ability-based grouping, task differentiation, and continuous formative feedback have high transferability power. The GASING method in this study can be understood as a local component that can be substituted: in other contexts, the same role can be played by other structured learning approaches that emphasize gradual reasoning, such as the *Concrete-Pictorial-Abstract* (CPA) that is widely used in Singapore and the United Kingdom, or the manipulative-based numeracy approach that is common in Sub-Saharan Africa. Thus, the original contribution of this study to the international academic community lies not in the uniqueness of the local instruments used, but in the empirical demonstration that the integration of structured reasoning approaches with ability-based differentiation produces substantial effects (Cohen's $d = 0.99$) even in the context of very limited resources a finding that is directly relevant to policymakers and education practitioners in countries developing that face similar challenges.

Conclusions

This study empirically proves that the integration of the GASING method with the Teaching at the Right Level (TaRL) approach significantly improves the critical thinking ability of grade III elementary school students on summation materials, with a substantial difference in mean improvement scores between the experimental group and the control group ($M = 44.60$ vs. $M = 24.65$; $t(86) = -4.640$; $p < 0.001$; Cohen's $d = 0.99$). This relatively large magnitude of the effect confirms that the advantages of the experimental group are not only statistically significant, but also practically meaningful. These findings confirm that the synergy between the graded reasoning-based approach (GASING) and ability-based cognitive differentiation (TaRL) creates optimal learning conditions for the development of the ability to analyze, justify, and evaluate inclusive math problem-solving strategies across the spectrum of students' abilities. Theoretically, this study strengthens the argument that Cognitive Load Theory and Proximal Development Zones can be used as complementary foundations in designing mathematical learning that encourages higher-level thinking. The integration of TaRL into GASING functionally reduces the extrinsic cognitive load while maximizing the active involvement of students in reasoning activities that are right at the limits of their actual abilities. In practical terms, this study shows that competency-based diagnostic assessments are a prerequisite for effective instructional design, and that differentiated learning models can be implemented in elementary schools without sacrificing the depth of students' thinking processes. These findings provide concrete guidance for teachers in designing mathematics learning that is more responsive, adaptive, and oriented towards reasoning development, rather than just procedural accuracy.

However, this study has a number of limitations that need to be acknowledged. First, the sample coverage is limited to six elementary schools in one sub-district, so the generalization of the findings needs to be done carefully. Second, the short duration of the intervention (two weeks, four sessions) limited the possibility of capturing long-term impacts. Third, the measurement of critical thinking relies on written test instruments only. Fourth, the use of raw gain scores (posttest – pretest) as a dependent variable, even though it has been considered psychometrically in the method section, still carries the potential limitation of comparability between individuals with very different starting points; The next study is suggested to explore normalized gain or covariance analysis (ANCOVA) with pretest scores as covariates as a more robust alternative. Further research is suggested to expand implementation to other mathematical domains (subtraction, multiplication, fractions) and more diverse levels of education, using randomized experimental designs with larger samples, and integrating multidimensional measurements including thought process observation and in-depth interviews to capture the long-term impact of the integration of GASING and TaRL on the sustainable development of students' critical thinking skills.

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