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Synergizing the GASING Method and Quantum Learning: An Effort to Optimize Elementary School Students' Mathematical Problem-Solving Abilities

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Abstract: The mathematical problem-solving abilities of elementary school students are still relatively low; this is caused by the high cognitive load they have to face when learning new complex materials and the lack of mental readiness to learn. This study aims to evaluate the effectiveness of the synergy between the GASING (Easy, Fun, Enjoyable) method and the Quantum Learning approach in improving elementary school students' mathematical problem-solving abilities. This study used a quantitative, quasi-experimental design (non-equivalent control group design) involving 140 3rd-grade elementary school participants in Singkawang City, with six schools selected through purposive sampling. The research instrument was a validated test item on mathematical problem-solving abilities. Data were obtained through pretest and posttest assessments, then analyzed quantitatively using Paired Sample T-Test and Quade's Rank Analysis of Covariance (ANCOVA) to address non-normally distributed residual data. The results of the study indicate that the experimental group experienced a significant increase in average scores, from 29.14 to 77.21 ($p < 0.001$). The results of the Quade's Rank ANCOVA test showed a significant difference between the two groups (F = 73.067, $p < 0.001$), with an effect size of 38.3% ($R^2 = 0.383$) in the large category. Analysis of the learning trajectory using a scatter plot showed that all students experienced a steady increase in their skills, with no extreme outliers. This study concludes that the synergy of the GASING method and the Quantum Learning approach can reduce students' cognitive load through systematic deconstruction of material while creating a learning environment that supports their mental readiness. This framework provides an effective teaching method for educational practitioners to address mastery of classical mathematics competencies.

Keywords: GASING method, quantum learning, problem-solving abilities, mathematical competence, elementary school.

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INTRODUCTION

Problem-solving ability is a fundamental skill needed within the educational framework of the 21st century (Rahman, 2019; Sardar, 2024). Students use this ability to break down complex mathematical problems into simpler, logical steps that they can understand at their current ability level (Habib et al., 2024; Kathayat, 2024; William & Maat, 2020). However, field conditions indicate a significant difference between the two, as students still fail to develop problem-solving skills, hindering their ability to learn mathematics at the elementary school level. International indicators, as reported by the OECD (2023), show that Indonesia achieved a low PISA 2022 mathematics score of 366, below the global average. The 2023 National Assessment data (ANBK) show that Indonesian students scored below the OECD average in both literacy and numeracy, indicating significant deficiencies in critical thinking and problem-solving skills (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2024). Students at this stage of education struggle with non-routine problems because they rely on memorizing mechanical procedures without developing a deep understanding of concepts. The education system will be adversely affected if this skills gap remains unaddressed, as it will limit students' ability to acquire the numeracy and critical-thinking skills needed for their future academic studies.

In line with the results of PISA and ANBK, a report from the Singkawang City Education Office shows that elementary school students in Singkawang City achieved a numeracy score of 59.28, which is still below the national average score of 67.94 according to data from the report (Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2025). The current state of schools shows that most students can only perform basic calculations without a deep understanding of mathematical concepts. Students who lack these skills face obstacles when solving real-life problems that require logical reasoning and mathematical skills (Adu-Gyamfi et al., 2025; Domu & Mangelep, 2024). This learning gap indicates an urgent need to transform existing educational methods that rely on theoretical frameworks and lack practical applications.

Based on this, the main problem in this study is the low level of mathematical problem-solving abilities among elementary school students. This condition is intrinsically linked to the procedural mathematics learning paradigm, which largely focuses on the final result, rather than on students' cognitive processes. Teachers often prioritize the distribution of formulas and the implementation of routine exercises, thereby failing to provide students with a path to develop deep conceptual understanding (Hussein, 2022; Kim, 2020). As a result, the educational experience becomes monotonous, passive, and meaningless for students. International research shows that procedural learning improves mechanistic skills, but does not significantly improve non-routine problem-solving abilities (Faulkner et al., 2021). Furthermore, evidence suggests that an exclusive focus on procedural teaching can hinder the acquisition of conceptual knowledge essential for higher-order problem solving (Hurrel, 2021).

Contemporary mathematics education has fostered initiatives to diversify pedagogical frameworks and enhance students' abilities in higher-order cognitive processes. However, empirical data suggest that fundamental challenges persist, with many elementary school students failing to achieve adequate proficiency in mathematical problem-solving skills. A large number of empirical investigations at the national level reveal that students face significant challenges when solving contextual problems and applying appropriate strategies in mathematics, a phenomenon that aligns with the results of international assessments used as benchmarks for educational quality (Csernicsko et al., 2025; Cruz, 2025). Furthermore, recent empirical research in Indonesia illustrates the differential effectiveness of two related methodologies aimed at addressing this issue: the GASING (Easy, Fun, and Enjoyable) method, which provides concrete, engaging, and systematic learning strategies to enhance understanding of mathematical concepts (Surya & Surya, 2026), and the Quantum Learning approach developed by Bobbi DePorter and Mike Hernacki based on Dr. Lozanov's accelerated learning theory and Gardner's multiple intelligences framework, both of which suggest that learning effectiveness is enhanced when combining positive emotional engagement, a learning environment, and multisensory experiences (Julita et al., 2019; Raisinghani & Kesur, 2024). The combination of these two methods is believed to be an effective pedagogical approach for addressing low levels of mathematical problem-solving among elementary school students.

Research shows that the Quantum Learning approach enhances student engagement in higher-order cognitive processes through its role as a framework for educational development (Chiofalo et al., 2022; Yigiter, 2023), while the GASING method has demonstrated efficacy in improving numerical operational accuracy (Dalughu & Kurniawati, 2025; Surya & Surya, 2026). However, a literature review reveals two crucial research gaps: although effective in isolation, their implementation is dichotomous: the GASING method often focuses on structured conceptual mastery, whereas Quantum Learning places greater emphasis on managing the learning environment without specific mathematical content structures. The logic behind this synergy rests on the understanding that students need both structured conceptual fluency and emotional stability to succeed in mathematical problem-solving (Callaman & Palompon, 2026; Martin-Requejo et al., 2023; Martinez-Pedron, 2021). The current research addresses this gap by applying GASING cognitive deconstruction to create simplified problem solutions while utilizing Quantum Learning acceleration strategies to address emotional barriers. Therefore, quasi-experimental research needs to continue because it will evaluate both methods through new effectiveness assessments and study how their combined effects will yield extraordinary problem-solving developments that cannot be achieved if the methods are implemented in part.

The synergy between the GASING method and the Quantum Learning approach is based on their ability to function together through cognitive abilities and the educational environment. The GASING theoretical framework employs cognitive deconstruction to break down complex mathematical concepts into basic elements, thereby reducing students' cognitive load (Sweller, 2023). Research shows that students must be mentally prepared, as this reduction in cognitive load is effective only when they are in that state (Hawthorne et al., 2019; Jordan et al., 2020). Quantum Learning creates an educational environment that helps students prepare to learn by supporting their emotional well-being and brain development. This system establishes a conceptual framework that uses Quantum Learning to create pathways that reduce emotional inhibitions, while GASING functions as a content processor, ensuring efficient information processing in working memory. The learning process becomes harmonious through this synergy, which combines technical procedures with psychological comfort, thereby enhancing students' ability to solve mathematical problems (Devi et al., 2024; Shimizu, 2022).

The conceptual framework of this study explicitly demonstrates how it connects the two approaches through the principle of "conditioning and processing." Quantum Learning serves as an environmental conditioning phase that builds a classroom for inclusive learning, along with positive affirmation techniques that reduce barriers to emotional processing (Yildiz & Bayram, 2025). The GASING deconstruction mechanism serves as a cognitive processing phase when the learning space achieves psychological safety. This synergy ensures that the simplified GASING material reaches students with high operational readiness due to the Quantum Learning intervention. Thus, this integration process is not simply a combination of two methods, but rather an instructional design that facilitates the transfer of information from the external environment into students' cognitive schemas, achieved through a balance between emotional comfort and procedural ease.

While the integration of the GASING method and Quantum Learning approach offers potential benefits for mathematics learning, it is not without some conceptual and practical challenges. The overlap between the structured stages of GASING and the flexible principles of Quantum Learning can lead to pedagogical inefficiencies if not carefully designed. Furthermore, combining multiple activities within a single learning sequence can increase cognitive load for elementary school students, especially those with lower ability levels, thereby hindering conceptual understanding and problem-solving (Huang, 2018; Ngu & Phan, 2024). From an implementation perspective, effective integration requires significant pedagogical competence from teachers, who must authentically apply the principles of GASING and Quantum Learning. Inadequate training can lead to shallow implementation (Axmedova, 2025). Therefore, empirical testing of the integration is crucial, focusing not only on learning outcomes but also on the pedagogical feasibility and sustainability of its classroom implementation.

This study introduces a major innovation by combining the GASING method and the Quantum Learning approach into a cohesive, transformative educational framework. The dual approach in this study maintains a commonality through a humanistic educational method that defines happiness and meaningful learning as essential components of knowledge acquisition. The GASING method breaks down mathematical complexity into simple steps to reduce intrinsic cognitive load. At the same time, Quantum Learning creates an educational space that supports optimal brain development through emotional management and multisensory learning experiences. This unique integration creates a functional interdependence: GASING provides structured, systematic cognitive material, while Quantum Learning provides an emotional context that helps learners grasp it more quickly. Quantum Learning in mathematics tends to lack a strong technical framework without GASING, while GASING without Quantum Learning risks becoming a dry, structured concept lacking emotional engagement. This study addresses the limitations of previous studies (Hendriana et al., 2019; Nahar et al., 2022), which examined these methods in isolation. This new pedagogical framework uses GASING and Quantum Learning methods to develop advanced problem-solving skills that prior research has not thoroughly explored.

Given the theoretical and empirical shortcomings described above, this study aims to examine the synergistic effectiveness of the GASING method and the Quantum Learning approach in improving elementary school students' mathematical problem-solving abilities. The specific objectives of this study include: (1) measuring the improvement in mathematical problem-solving competencies of students engaged in learning through the GASING method based on the Quantum Learning approach compared to those who participated in group discussions based on the Contextual Teaching and Learning (CTL) approach, and (2) explaining the differences in problem-solving ability improvement between the two learning groups. Pragmatically, the purpose of this study is to create an alternative, humanistic, active, and enjoyable framework for mathematics learning that elementary school teachers can use to help students develop higher-order thinking skills. Theoretically, this study is expected to contribute to existing research on integration-oriented pedagogical innovations within the framework of cognitive learning and conducive learning environments (Engin et al., 2024; Wang et al., 2020), and improve the direction of autonomous curriculum policies aimed at improving critical thinking and problem-solving abilities (Badan Standar, Kurikulum, dan Asesmen Pendidikan [BSKAP], 2024).

From a theoretical perspective, this study strengthens the humanistic-constructivist paradigm in elementary mathematics learning by integrating the GASING method and the Quantum Learning approach, which emphasize a balance between cognitive dimensions and the learning environment. Consistent with findings

(Mukherjee, 2025), pedagogical strategies that combine cognitive scaffolding with psychological reinforcement, such as constructivist, dialogic, and experiential modalities, increase cognitive flexibility and reduce anxiety, thereby strengthening the humanistic-constructivist paradigm in elementary mathematics learning by simultaneously addressing cognitive and emotional aspects. In the context of Indonesian education, this study serves to provide a learning model that aligns with the characteristics of Indonesian elementary school students while facilitating the implementation of the Independent Curriculum, which prioritizes the development of critical thinking skills and contextual problem-solving (Badan Standar, Kurikulum, dan Asesmen Pendidikan [BSKAP], 2024). The combination of these two approaches is expected to produce a transformative model that teachers, educational institutions, and curriculum developers can use as a reference to advance mathematics learning at the elementary school level. Furthermore, the findings of this study are expected to provide an important evidence-based approach to the literature on innovative mathematics teaching in Indonesia and abroad. Therefore, this study not only contributes to improving the quality of national mathematics learning but also expands the global scientific discourse on integrative learning strategies rooted in humanistic and cognitive frameworks. The research questions are as follows:

1. Is the synergy of the GASING method and the Quantum Learning approach able to significantly improve the mathematical problem-solving abilities of elementary school students?
2. Is there a difference in improving mathematical problem-solving abilities in students who receive the synergy of the GASING method and the Quantum Learning approach compared to students who receive the group discussion method and the Contextual Teaching and Learning (CTL) approach?

Based on theoretical studies and prior research, this study formulates a hypothesis to test the synergistic effect of the GASING method and the Quantum Learning approach on elementary school students' mathematical problem-solving abilities. As a first step in answering the research questions that have been proposed, these hypotheses are formulated as follows:

1. The effectiveness of the synergy of the GASING method and the Quantum Learning approach to improving the mathematical problem-solving abilities of elementary school students.

   Null hypothesis (H_0): There is no significant increase in the synergy of the GASING method and the Quantum Learning approach on the mathematical problem-solving abilities of elementary school students.

   Alternative hypothesis (H_a): There is a significant increase from the synergy of the GASING method and the Quantum Learning approach on the mathematical problem-solving abilities of elementary school students.
2. The difference in the improvement of mathematical problem-solving abilities between students who received the synergy of the GASING method and the Quantum Learning approach, and students who received the group discussion method based on the CTL approach.

   Null hypothesis (H_0): There is no significant difference in the improvement of mathematical problem-solving abilities between students who received the synergy of the GASING method and the Quantum Learning approach and students who received group discussion methods and the CTL approach.

   Alternative hypothesis (H_a): There is a significant difference in the improvement of mathematical problem-solving abilities between students who received the synergy of the GASING method and the Quantum Learning approach, and students who received the group discussion method and the CTL approach.

■ METHOD

Participant

The study population comprised third-grade students enrolled in public elementary schools in Singkawang City, West Kalimantan Province, during the odd semester of the 2025/2026 academic year. The sample for this study was selected using purposive sampling, taking into account input from educational practitioners and the results of the institutions' initial evaluations. The primary rationale for using this technique, rather than simple random sampling, was to minimize disruption to established classroom dynamics and the continuity of instructional schedules at the collaborating educational institutions. Randomization of individuals in the elementary education domain is often challenging due to administrative constraints and the need to maintain a stable pedagogical environment during the intervention phase (Brown et al., 2022; Spybrook et al., 2020). However, to mitigate potential selection bias, the researchers administered a pretest to verify that the experimental and control groups had comparable baseline abilities before the intervention. The authors acknowledge that the use of this non-probabilistic technique limits the broader generalizability of the study's findings; however, it was chosen to increase ecological validity in an authentic classroom context (Andrade, 2021; Memon et al., 2025). From this population, six public elementary schools were systematically selected as research samples: three designated as the experimental group and three as the control group. The total number of participants was 140 students, with an average of 23-24 per school. This sample selection is expected to effectively represent the overall characteristics of third-grade students in the Singkawang city area by selecting six schools with dominant and similar accreditation backgrounds across groups and spread across each sub-district. The following is a table of the distribution of the research sample:

Table 1. Distribution of research samples at SDN singkawang city

Group	School name	Number of Students	Treatment
Experimental	SDN 64	23	GASING + Quantum Learning
	SDN 92	24	
	SDN 93	23	
Control	SDN 17	24	Group Discussion + CTL
	SDN 85	23	
	SDN 91	23	
Total	**6 Schools**	**140**	

Research Design and Procedures

This study employed a quantitative method featuring a quasi-experimental design with a non-equivalent control group setup. It involved two groups of students: the experimental group and the control group. This method was chosen due to the constraints researchers face in controlling the classroom environment, particularly when they lack authority over student assignments. A quasi-experimental design allows researchers to study educational phenomena in a natural setting, making it suitable for contexts where random assignment is impractical or unethical (Gopalan et al., 2020; Kim & Clasing-Manquian, 2023). The experimental group engaged in mathematics learning using the GASING method based on the Quantum Learning approach. In contrast, the control group learned through group discussions based on the Contextual Teaching and Learning (CTL) approach. This design facilitated a comprehensive analysis of changes in mathematical problem-solving abilities by allowing for a comparative examination of pretest and posttest results between the two groups. The following is a quasi-experimental research design.

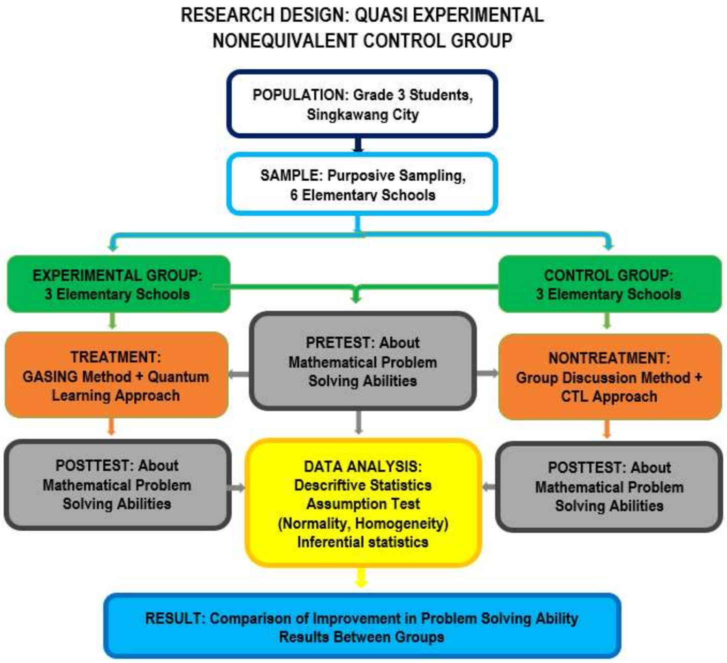

Figure 1. Quasi-experimental research design

In this study, selection bias was controlled through matching techniques and covariate controls to enhance the validity of the results. Matching techniques were initially used to align interclass characteristics and similar school accreditation backgrounds between the two groups. Given the limited sample size, the researchers used Quade's Rank ANCOVA to control for covariates in the presence of non-normally distributed data, including pretest scores as a control variable. This approach aims to statistically adjust for differences in baseline ability, ensuring that the research results accurately reflect the effectiveness of the intervention rather than pre-existing differences in quality.

This study adhered to the ethical framework governing educational research, including obtaining approval from the education office, the schools, and the teachers involved, as well as obtaining informed consent from the students' parents. All data were collected while maintaining student anonymity and were used exclusively for scientific purposes. Learning activities in the experimental group were carefully designed to align with the established school curriculum and not burden either students or teachers. This study also adhered to the ethical principles of non-maleficence and beneficence, which require avoiding any action that could harm students while ensuring that research efforts yield tangible benefits for improving mathematics learning in primary education institutions. The expected outcomes of this research effort aim not only to add to the academic discourse but also to provide pragmatic insights for teachers in formulating effective, engaging, and meaningful learning experiences for students.

The research implementation was divided into three main phases: (1) preparation, (2) implementation, and (3) evaluation. The preparation phase included activities related to needs analysis; development of learning materials (including teaching modules, teaching materials, LKPD, and assessment instruments); validation of these instruments by competent experts in their fields; and empirical testing of the research instruments to strengthen their validity and reliability. The implementation phase began with the administration of a validated pretest assessing mathematical problem-solving abilities, followed by 5 group meetings, with a total time allocation of 3 x 30-minute sessions. The main material taught was the addition of whole numbers up to 999. In the experimental group, the structure of each session was designed to balance emotional readiness and cognitive strengthening with the following details:

Teachers received training in applying the GASING method, which aligns with the principles of the Quantum Learning approach, before and after the intervention to strengthen their understanding.

Table 2. Flow of synergy intervention of the GASING method and quantum learning

Session	Specific Material	GASING-Quantum Learning Time Allocation	Form of Activity
1	Introduction and Addition of Whole Numbers Up to 19	1. Grow & AMBAK (Quantum Learning): 10 minutes per session	Ice breaking, apperception, starting questions, conveying learning objectives, and benefits.
2	Introduction and Addition of Whole Numbers 20-99	2. Concrete and abstract stages (GASING); Experience, Name, and Demonstrate (Quantum Learning): 50 minutes per session	Explaining material with concrete objects, demonstrating, and students giving examples.
3	Introduction and Addition of Whole Numbers 100-999		
4	Solving Problems Adding Whole Numbers Up to 999	3. Mencongak Stage (GASING); Repeat and Celebrate (Quantum Learning): 20 minutes per session	Drill (repeating questions), playing games, and showing appreciation.
5	Contextual Problem Solving for Adding Whole Numbers Up to 999		

Meanwhile, the control group underwent the learning process typically conducted in schools, namely, a group discussion method based on the CTL approach. The learning sessions were systematically designed during their implementation, as shown in Table 3.

Table 3. Flow of control class implementation

Stages	Learning Session	Student Specific Activities
Constructivism	Introduction	Students connect their prior knowledge to real-world problems presented by the teacher as discussion topics.
Inquiry	Beginning of group discussion	Students make observations, collect data, and investigate problems in small groups and work independently to find initial solutions.

Learning Community	Core process of discussion	Students engage in dynamic interactions within diverse groups, exchange insights with one another, and collaboratively solve problems.
Questioning	Question and answer between groups	Students ask questions to peers and other groups to deepen their understanding of concepts.
Modeling	Demonstration/ Presentation	Students see a model (either a peer presentation or a teacher example) that illustrates how to integrate an idea into everyday practice.
Reflection	Closing discussion	Students write down their impressions, summaries, or new things they have learned during the discussion process.
Authentic Assessment	Final evaluation	Student assessment is based not only on final results but also on their active participation, how they discuss, and their presentation skills.

This framework requires the discussion method to serve as an educational platform for community members to develop their inquiry skills. The teacher uses their role as a facilitator to help students develop high-quality questions about the learning material. The model's primary focus examines how students in a constructivist learning environment develop their understanding through the practical experiences they share with their classmates. The teacher in this classroom environment does not employ any specific number deconstruction techniques or any specific learning atmosphere conditioning that characterizes the synergy between the GASING method and the Quantum Learning approach. This description establishes a fair method for measuring both classes because the different outcomes result from the unique operational characteristics of the GASING method and the Quantum Learning system. After completing the learning process for both groups, a posttest was administered. The final phase, the most important in this discussion, is the evaluation phase. In this phase, researchers review the findings, interpret the data, and determine whether the research objectives have been achieved. A detailed evaluation not only summarizes the research's success but also offers insights for future research and advances knowledge (Nnachi et al., 2024).

Instrument

The primary research instrument for this study was a mathematical problem-solving ability test, which included essay questions. This instrument was adapted from problem-solving indicators developed by Prabawanto (Prabawanto, 2013), which assess students' cognitive processes through their learning outcomes. Table 3 below presents the details of the indicators, along with operational definitions and sample test items.

Table 4. Specifications of the mathematical problem-solving abilities instrument

Indicators (Prabawanto, 2013)	Operational Definition	Sample Question Items
1. Solving closed mathematical problems in a mathematical context.	Students' ability to understand and solve closed-ended mathematical problems means there is one correct answer, and the context is purely	If a number is added to the number 231, the result is 457. Then, if it is added to the number 342, the result is 568. What is that number?

<table>
<tr><td></td><td></td><td>mathematical, without real-life situations.</td><td></td></tr>
<tr><td>2.</td><td>Solving closed mathematical problems outside the context of mathematics.</td><td>Students' ability to understand, plan, and solve simple story problems or contextual situations with one correct answer, drawn from everyday life, and solved using mathematical operations.</td><td>A warehouse issued rice for sale to a grocery store over four days. The resulting output is shown in the following table:

Tabel Pengeluaran Beras
<table>
<tr><th rowspan="2">Hari</th><th colspan="2">Banyak beras keluar (kg)</th></tr>
<tr><th>Pagi</th><th>Sore</th></tr>
<tr><td>Senin</td><td>126</td><td>372</td></tr>
<tr><td>Selasa</td><td>253</td><td>246</td></tr>
<tr><td>Rabu</td><td>365</td><td>121</td></tr>
<tr><td>Kamis</td><td>264</td><td>173</td></tr>
</table>
On which day does the most rice come out in 1 day?</td></tr>
<tr><td>3.</td><td>Open mathematical problem solving in a mathematical context.</td><td>Students' ability to solve open-ended problems, where there is more than one possible correct answer in a pure mathematical context (e.g., finding pairs of numbers with a certain sum).</td><td>Write three different ways to get the result 670, from the sum of two numbers! Each number consists of three digits.</td></tr>
<tr><td>4.</td><td>Open mathematical problem solving outside the context of mathematics.</td><td>Students' ability to solve real (contextual) problems that are open, that is, they can be solved in various ways or with reasonable answers.</td><td>There are 475 books in the library. There are more math books than science books, and science books than Indonesian books. The number of math and science books is even, while the number of Indonesian books is odd. Write down two possible ways to find each number.</td></tr>
</table>

The validation protocol was conducted through two distinct phases: content validity and construct validity (empirical testing). Content validity was assessed through expert judgment by two mathematics education experts using Aiken's V coefficient, where V > 0.80 indicates high validity (Aiken, 1985). The content validity results showed an Aiken's V coefficient (overall mean value) of 0.97 (high validity category). Empirical testing (validity and reliability) was conducted with 45 students outside the research sample to evaluate the internal consistency of the test items using Pearson's product-moment correlation coefficient. The correlation coefficient results for 10 test items were > 0.301, indicating construct validity, while 2 items were < 0.301 and were eliminated. Furthermore, the assessment instrument's reliability was assessed using Cronbach's alpha (á = 0.77), indicating high reliability (George & Mallery, 2019). Therefore, the instruments used to assess mathematical problem-solving abilities in this study are considered valid and reliable, thus confirming their efficacy in measuring the variables studied.

Data analysis

Data were obtained using a mathematical problem-solving abilities assessment instrument developed by the researchers, based on indicators of mathematical problem-solving abilities. The assessment was conducted in a two-phase format, consisting of a pretest before the intervention and a posttest after, using a series of descriptive questions requiring mathematical reasoning and argumentation. The evaluation matrix was based on an analytical rubric that included four main indicators of problem-solving skills, with a rating scale ranging from 0 to 3 for each question. The data collection process was carried out systematically as follows:

1. Pretest: Pretest was given to both groups (experimental and control) to ensure students' basic abilities in mathematical problem-solving competencies.
2. Treatment: The experimental group was involved in learning using the GASING method based on Quantum Learning, while the control group received instructions through a group discussion method based on the CTL approach.
3. Posttest: After all learning sessions were completed, both groups were given a test that had the same characteristics as the pretest to evaluate progress in problem-solving abilities.
4. Data collection and analysis: Assessment results are collected systematically, evaluated according to established assessment criteria, and analyzed using parametric or non-parametric tests to determine whether there is an improvement in results and significant differences between groups.

To answer the research question about the effectiveness of the GASING method, based on the Quantum Learning approach, in improving elementary school students' mathematical problem-solving abilities, the data analysis used a paired-sample t-test when the data were normally distributed and a paired-sample sign test when they were not. Before the paired-sample t-test is conducted, the prerequisite test (normality) must be met. Meanwhile, to determine the extent to which the intervention increased, the N-Gain (Normalized Gain) test was used. Furthermore, to determine whether there was a difference in the improvement in mathematical problem-solving abilities between the experimental and control classes, data were analyzed quantitatively while controlling for students' initial abilities. The researchers used Quade's Rank ANCOVA to analyze the data in this study and anticipate potential clustering bias and redundancy in the results. The researchers chose this testing method to address violations of the normality assumption that often occur in educational research data with small to medium sample sizes (Fan & Zhang, 2017; Quade, 1967). The Quade procedure is a non-parametric approach that allows researchers to compare groups while controlling for pretest effects through rank transformation, because the standard ANCOVA method is heavily influenced by data distributional anomalies. The analysis procedure requires three steps that include testing the classical assumptions through a normality test, Levene's test for homogeneity of variance, and an assessment of linearity, followed by testing the homogeneity of regression between the covariates and the dependent variable. Standard ANCOVA will be used for comparison when the data meet all parametric assumptions. However, Quade's Rank ANCOVA will serve as the primary analysis tool to ensure valid statistical results and reduce Type I errors when estimating the effectiveness of the GASING method and the Quantum Learning approach. Researchers will also assess the practical significance of the intervention in the field using effect size calculations based on Partial Eta Squared, following Cohen's guidelines for effect sizes.

Further analysis was conducted for all four specific indicators, which include: (1) solving closed mathematical problems in a mathematical context, (2) solving closed mathematical problems outside a mathematical context, (3) solving open-ended problems in a mathematical context, and (4) solving open-ended mathematical problems outside a mathematical context. The researchers conducted the Mann-Whitney U test to assess differences between the experimental and control groups for each specific indicator. The researchers applied the Bonferroni correction to reduce the risk of Type I error in multiple comparisons by setting the significance threshold at á = 0.0125 (0.05/4). The researchers calculated the effect size to assess the intervention's impact across all dimensions.

This analysis provides quantitative evidence of improved learning outcomes resulting from the instructional intervention. All analyses were conducted using IBM SPSS Statistics version 22, and the results were manually verified for accuracy. The following are metrics for the study's data collection and analysis techniques:

Table 5. Metrics of research data collection and analysis techniques

Research Questions	Instrument	Data source	Instrument's Shape	Data Analysis Techniques
1. Is the synergy of the GASING method and the Quantum Learning approach able to significantly improve the mathematical problem-solving abilities of elementary school students?	Mathematical problem-solving abilities test (pretest and posttest).	Experimental class students	Essay/descriptive test questions: Short descriptions, open descriptions, and story problems.	1. Prerequisites: Normality test (Kolmogorov-Smirnov/Shapiro-Wilk) 2. Parametric: Paired sample t-test (if the data is normal). 3. Non-parametric: Paired sample sign test (if the data is not normal). 4. N-Gain Test.
2. Is there a difference in improving mathematical problem-solving abilities in students who receive the synergy of the GASING method and the Quantum Learning approach compared to students who receive the group discussion method and the Contextual Teaching and Learning (CTL) approach?	Mathematical problem-solving ability test (pretest and posttest).	Students in the experimental class and the control class	Essay/descriptive test questions: Short descriptions, open descriptions, and story problems.	1. Prerequisites: Normality (Kolmogorov-Smirnov/Shapiro-Wilk), homogeneity of variance (Levene's test), linearity, and homogeneity of regression. 2. Parametric: ANCOVA (Analysis of Covariance) with pretest scores as a covariate (if the data is normally distributed) 3. Non-parametric: Quade's Rank Analysis of Covariance (if the

data is not normally distributed), Mann-Whitney U Test (performed to compare the two groups at the indicator level).

4. Effect Size: Partial Eta Squared estimate, following Cohen's standard effect size.

■ RESULT AND DISCUSSION

The data analysis process was carried out in two main phases: Formal prerequisite testing and hypothesis testing to answer two research questions regarding the effectiveness of the synergy of the GASING method and the Quantum Learning approach.

Synergy of the GASING and Quantum Learning Methods to Improve the Mathematical Problem-Solving Abilities of Elementary School Students.

The researchers began their analysis by testing whether the experimental classes implementing the GASING and Quantum Learning methods showed improvements in their test scores. The researchers first conducted a normality test to determine which statistical method to use for hypothesis testing. This prerequisite test aims to ensure that the research data meet the basic requirements for parametric testing, so that the hypothesis-testing results can be interpreted and justified scientifically (Kim & Park, 2019; Sharma & Jha, 2023). The normality test was conducted by examining the significance of the difference between the posttest and pretest results. students' mathematical problem-solving abilities.

Table 6. Results of the shapiro-wilk normality test

	Shapiro-Wilk		
	Statistics	**df**	**Sig.**
Differences in Problem-Solving Abilities	0.973	70	0.134

Based on the results of the Shapiro-Wilk test, the data on the difference in problem-solving ability show a statistical value of $W(70) = 0.973$, $p = 0.134$, because the Sig. value > 0.05 indicates that the data are normally distributed, allowing the researchers to proceed with their parametric statistical tests. The following is a table of paired sample t-test results:

Table 7. Paired sample statistics

		Mean	**N**	**Std. Deviation**	**Std. Error Mean**
Pair 1	Problem-Solving Abilities Pretest	29.1429	70	17.04494	2.03726
	Problem-Solving Abilities Posttest	77.2143	70	15.69907	1.87640

Table 8. Paired sample t-test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	**Standard Deviation**	**Std. Error Mean**	**Lower**	**Upper**	**t**	**df**	**Sig. (2-tailed)**
Pair 1	PrePSA-PostPSA	-48.07143	21.98044	2.62717	-53.31248	-42.83038	-18.298	69	.000

Based on descriptive statistics (Table 7), there is a significant increase in the average score, from a pretest score of 29.14 (SD = 17.04) to a posttest score of 77.21 (*SD* = 15.70). Statistical analysis (Table 8) yields t(69) = -18.298, $p < 0.001$. This indicates that H_0 is rejected and H_a is accepted, and that the synergistic intervention of the GASING and Quantum Learning methods has a real positive influence on students' mathematical problem-solving abilities. A deeper review of individual students' learning trajectories is obtained through the scatter plot in Figure 2, which displays the distribution of pretest and posttest scores.

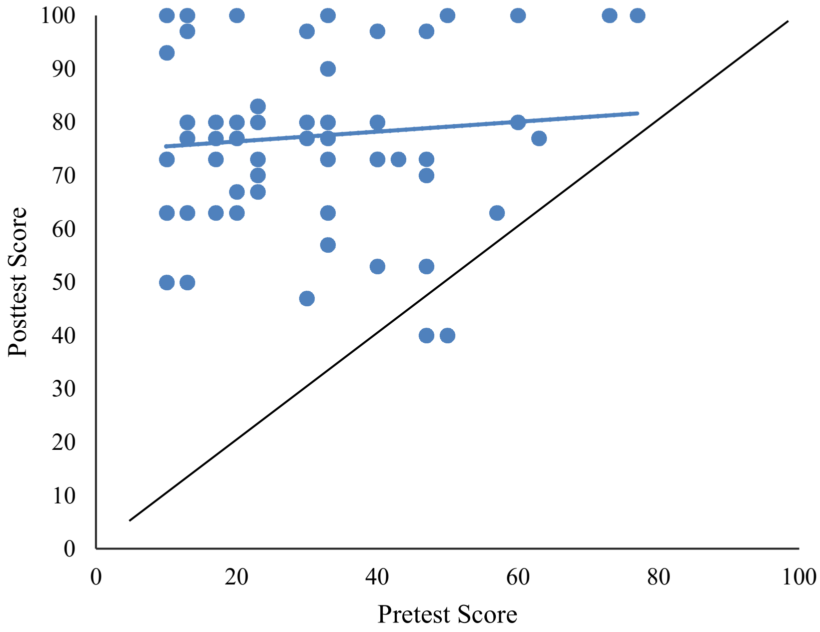

Figure 2. Scatter plot of the pretest-posttest score trajectory of experimental class students

The scatterplot visualization of the above data (Figure 2) shows positive learning progress, as nearly all data points move above their initial pretest horizontal positions to a higher posttest area. The scattered data reveals several important points to note:

1. Individual Learning Trajectories: The majority of students who started with low abilities in the 10 to 40 range achieved high scores between 70 and 95 after receiving treatment. Research shows that combining the GASING and Quantum Learning methods yields optimal results for students who start with low academic skills.
2. Outlier Identification: The data distribution shows a pattern that follows a linear trendline (the solid blue line). Every student who

participated in the study improved their scores, but their rates of progress varied, and there were no extreme outliers, indicating that the intervention did not fail.

3. Consistency of Effect: The area on the right side of the graph shows a high concentration of dots, indicating that the intervention produced a stable impact that helped students master problem-solving skills through group learning. Improvements that developed over time provide strong evidence that the synergy of GASING (which simplifies cognitive content) and Quantum Learning (which creates an optimal emotional learning space) enables students to learn more effectively by removing their learning barriers.

Researchers examined how the GASING and Quantum Learning methods produced better results based on student abilities. The researchers divided both classes into three groups based on their pre-test scores: Low (scores below 33), Medium (scores between 33 and 55), and High (scores above 55). The researchers evaluated the effectiveness of the intervention using normalized gain scores (N-Gain), which they divided into three categories: Low (< 0.3), Medium (0.3 to 0.7), and High (> 0.7).

Based on the data (Table 9), crucial findings regarding the pedagogical fairness of the intervention are revealed. The main findings showed that the experimental group of students with lower abilities demonstrated greater improvement than the control group of students with similar academic levels. The low-ability experimental group achieved an average N-Gain of 0.72, enabling them to reach a "High" level of performance and move from basic to advanced understanding. Meanwhile, the control group of students with low ability progressed from the "Low" to the "Medium" level of performance, as indicated by an N-Gain score of 0.46.

Table 9. Analysis of N-Gain effectiveness based on initial ability level

Ability Category	Group	N	Pretest Average	Posttest Average	N-Gain Score	N-Gain Category
Low (< 33)	Experimental	40	16.88	76.74	0.72	High
	Control	28	22.61	57.93	0.46	Medium
Medium (33 - 55)	Experimental	23	39.78	74.57	0.58	Medium
	Control	31	41.48	54.03	0.21	Low
High (> 55)	Experimental	7	64.29	88.57	0.68	Medium
	Control	11	63.27	55.73	-0.21	Low

This study shows that the GASING method combined with the Quantum Learning approach yields better outcomes for students with low academic ability, as students in this study achieved a posttest score of 76.74, which exceeds the posttest score of students with low academic ability in the control group, who obtained 57.93. The intervention showed consistent N-Gain scores between 0.58 and 0.72, indicating that this method works well for all students and yields optimal improvement for each student in this study. This study shows that the step-by-step material deconstruction method used in GASING, together with the Quantum Learning environmental management, produces effective results for students with cognitive difficulties to achieve the required competency standards.

The research team conducted a comprehensive investigation of the problem-solving indicators developed by Prabawanto. The average score for each indicator, calculated by the researchers using N-Gain, is presented in Figure 3.

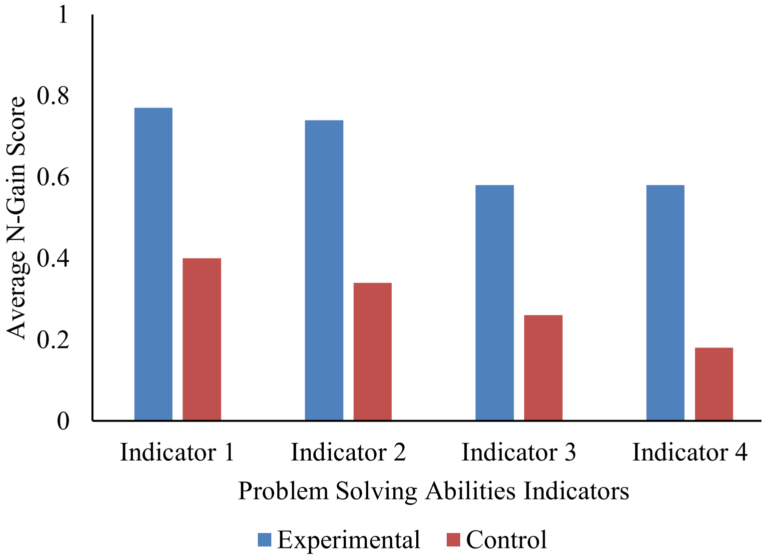

Figure 3. Results of data analysis on score increases per indicator

The average N-Gain score (Figure 3) shows the comparison between the experimental and control groups on four indicators of mathematical problem solving. The results show that students in the experimental class made greater progress than those in the control class across all measured indicators. The experimental group achieved a "High" level of improvement on Indicators 1 (solving closed mathematical problems in a mathematical context) and 2 (solving closed mathematical problems outside a mathematical context), with scores of 0.77 and 0.74, respectively. The control group achieved a "Medium" level of performance on the same indicators with scores of 0.40 and 0.34. The difference was striking on indicator 4 (solving open mathematical problems outside a mathematical context); the experimental class achieved a "Medium" score of 0.58. In contrast, the control class dropped to a "Low" score of 0.18. These results emphasize that the synergy between the GASING method and the Quantum Learning approach yields superior outcomes in helping students improve their mathematical problem-solving skills compared with group discussion methods and the CTL approach.

Comparison of Effectiveness Between Classes

The researchers used inferential statistical testing to evaluate the effectiveness of the synergy of the GASING method and the Quantum Learning approach compared to the group discussion method and the CTL approach. The initial testing procedure began with the Shapiro-Wilk test to assess the normality of the residual data. The test results showed W(140) = 0.972, with a significance level of $p = 0.005$ ($p < 0.05$). The results showed that the residual data were not normally distributed, so it was not appropriate to use parametric ANCOVA. This study used Quade's Rank ANCOVA because the research design included this method as a planned solution to manage potential data abnormalities that may occur in educational data. The results of the homogeneity of variance test showed compliance with the required standards, with F(1, 138) = 3.440 and $p = 0.066$ ($p > 0.05$). The homogeneity test for the regression line examining the interaction between class and pretest scores yielded F(1, 136) = 1.152, p = 0.285, indicating that the regression slope was homogeneous across groups.

The researchers conducted hypothesis testing after ensuring that all analytical requirements were met using robust nonparametric methods. The results of the Quade's Rank ANCOVA test are shown in Table 10.

Table 10. Results of the inter-class difference test (Quad Rank ANCOVA)

ANOVA					
Unstandardized Residual					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	75411.351	1	75411.351	73.067	.000
Within Groups	142427.797	138	1032.085		
Total	217839.148	139			

Based on the results of Quade's Rank ANCOVA test (Table 10), the test yields F(1, 138) = 73.067, $p < 0.001$. Because $p < 0.05$, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_a) is accepted. This finding shows a significant difference between the two groups: students who learned through the GASING method based on the Quantum Learning approach, compared with students who learned through group discussions based on the CTL approach. The researchers conducted an effect size analysis to validate their research results. The regression analysis showed an R-squared value of 0.383 (Adjusted R-squared = 0.369). The researchers concluded that the synergy of the GASING and Quantum Learning methods resulted in a 38.3% improvement in students' mathematical problem-solving abilities. The study showed that the intervention produced a "Large Effect," confirming that it maintains statistical significance and strong practical effects in improving elementary school students' learning outcomes.

Additional inferential statistical analyses were performed for each problem-solving ability indicator to provide a more detailed understanding. The results of the analysis of mathematical problem-solving indicators using the Mann-Whitney U test are presented in the following table:

Table 11. Comparison of mathematical problem-solving indicators of the two groups using the Mann-Whitney U test

Indicator	Group	Mean Rank	Mann-Whitney U	Z-value	p-value	Remaks
Indicator 1	Experimental vs Control	88.87 vs 52.13	1164.000	-5.395	0.000 *	Significant
Indicator 2	Experimental vs Control	85.75 vs 55.25	1382.500	-4.467	0.000 *	Significant
Indicator 3	Experimental vs Control	87.16 vs 53.84	1283.500	-4.932	0.000 *	Significant
Indicator 4	Experimental vs Control	92.06 vs 48.94	941.000	-6.355	0.000 *	Significant

**Significance level after Bonferroni correction ($\alpha = .0125$)*

The results of the Mann-Whitney U test (Table 11) indicate that the experimental and control groups differed significantly across four indicators of mathematical problem solving. After Bonferroni correction at á = 0.0125, all indicators had p-values < 0.001, indicating that the experimental group consistently outperformed the control group. The fourth indicator showed the largest difference, with the experimental group achieving the highest average rating of 92.06 and the control group the lowest at 48.94. This finding was confirmed by a significant Z-value of -6.355. The synergy of the GASING method and the Quantum Learning approach proved to be an effective intervention, improving students' performance on their most difficult problem-solving tasks. Indicators 1, 2, and 3 also showed significant improvements, with the experimental group achieving average ratings between 85.75 and 88.87, while the control group performed at a much lower level.

The research findings show that the synergy between the GASING method and the Quantum Learning approach leads to a significant increase in students' mathematical problem-solving abilities. The experimental class showed a sharp increase in the average test score, from 29.14 to 77.21, thus providing evidence of the intervention's success in reducing the cognitive barriers faced by elementary school students when solving complex mathematical problems.

Cognitive Load Reduction Mechanism Through Synergy of the GASING Method and the Quantum Learning Approach

This study demonstrates that integrating the GASING method and the Quantum Learning approach achieves optimal information-processing capacity. The GASING method enables students to understand complex mathematical concepts by breaking them down into smaller, more easily understood parts. This process directly reduces the intrinsic cognitive load that acts as a barrier for elementary school students when they try to learn new mathematical algorithms (Sweller, 2023). This cognitive load reduction is achieved through Quantum Learning's environmental conditioning strategies. Quantum Learning creates a classroom environment that combines active learning with organized teaching methods to reduce unnecessary cognitive load. The results of this study are supported by the dual-channel hypothesis in learning, which holds that efficient cognitive performance requires a balance between content simplification and learning context management (Kelly, 2022; Mayer, 2024).

Proficiency in Multiple Dimensions of Problem Solving: From Routine to Non-Routine Tasks

The inferential analysis results of the experimental group showed superior performance across all indicators, as evidenced by their tests. This success was achieved through a qualitative analysis of students' essay responses. The experimental group demonstrated their ability to use a variety of strategies when solving non-routine problems. The cognitive framework built through the GASING method of deconstruction enabled students to transfer their knowledge when facing problems outside the context of pure mathematics. This differed from the control group, which followed a mechanical calculation method without developing a deep understanding of the concepts. The main errors in the control group were due to students' failure to transform real-world problems into appropriate mathematical models. The experimental group students demonstrated independent problem-solving skills, indicating that the GASING method of deconstruction effectively helped them learn the operational logic of mathematics before applying it to advanced mathematical contexts. The ability to break down problems into logical components is a key success factor in developing high-level mathematical literacy skills in this collaboration (Maslihah et al., 2020).

The Journey of Underachieving Students: Bridging the Competency Gap

This study found that students with low initial ability achieved their highest performance level. Subgroup analysis by pretest scores showed that students with low ability in the experimental group achieved an average N-Gain increase of 0.72, which falls within the high category. In contrast, the control group achieved lower results, placing them in the medium category. This study proves that the synergistic use of the GASING method and the Quantum Learning approach serves as an effective inclusion instrument. The GASING program uses structured teaching methods to provide students with the necessary support, while the Quantum Learning environment creates an inclusive space that helps students overcome their learning difficulties. This finding supports the argument that learning methods that combine explicit cognitive structures with measurable environmental support lead to successful competency advancement in classroom settings (Olimova, 2025).

Comparative Analysis with Conventional Contextual Approach

Although the Contextual Teaching and Learning (CTL) approach in a controlled classroom setting emphasizes the importance of real-world applications, empirical data suggest that CTL alone is insufficient to enhance problem-solving competencies to the same extent as the synergistic integration of the GASING method and the Quantum Learning approach. The CTL system lacks explicit procedural instruction that would help students learn the essential skills needed to solve complex essay problems through numerical deconstruction. This study presents a synergy that creates a direct link between the "why" of a problem, through the contextual phase of Quantum Learning, and the "how" to solve it effectively, through the GASING technique. This comparison demonstrates that successful elementary school mathematics instruction requires meaningful real-world contexts and appropriate cognitive tools (Icuspit, 2025).

Operational Integration of TAMAR Framework in Classroom Interventions

This study successfully improved mathematical problem-solving skills through its procedural framework, which combines the Quantum Learning phase with the GASING method. The researchers implemented their intervention program using the TAMAR framework, which comprises five stages: Grow, Experience, Confirm, Secure, and Celebrate. This operational framework serves as an instructional guide for implementing experimental variables, developed by the authors as an a priori conceptual synthesis rather than a new finding from the research data analysis.

The initial stage begins with the "Grow" phase, which aims to foster students' interest and curiosity in the core material through the AMBAK principle. The teacher begins the lesson by presenting students with real-life problems from everyday experiences and explaining how these problems benefit them. The Quantum Learning principle creates a positive classroom environment by using background music and positive affirmations that increase student motivation, thereby preparing students for learning activities. Next, the second stage, "Experience," provides students with the real-life experiences they need to understand abstract symbols. Students learn basic concepts through direct experience with real objects that serve as learning materials. The teacher uses this exploratory method to help students discover concepts independently, allowing them to their basic cognitive framework.

The third stage, "Confirm," forms the foundation of cognitive processing, where the GASING method of number deconstruction transforms complex content into easily understood logical units that address iso-cognitive aspects. Teachers reinforce, along with exercises that help students achieve optimal understanding. The fourth stage, "Secure," is designed to facilitate students' retention of understanding and foster a sense of psychological security regarding their abilities. Teachers present students with a variety of problems, including open-ended, non-routine questions, to assess their ability to think flexibly. Furthermore, teachers provide direct constructive feedback to students. If errors occur, teachers use the GASING technique to redirect students without diminishing their self-esteem, thus ensuring that students' confidence remains intact.

The final stage is "Celebrate," recognizes students for their academic achievements, helping them create long-term memories while increasing their enthusiasm for learning. Teachers provide appreciation after each training session or problem-solving activity. Celebrations can take the form of special applause such as "Great Applause," verbal praise, and other small celebratory activities. The principle of Quantum Learning states that recognition strengthens neural connections associated with newly acquired knowledge (Chen & Zhang, 2025). When TAMAR is positioned as an instructional design framework, success in improving mathematical problem-solving skills, as indicated by quantitative data, can be understood as the result of a structured, effective, and procedurally consistent learning system.

Design Limitations and Integrity

This study has limitations identified by the researchers, such as the absence of standard affective scales for anxiety and motivation, which prevented researchers from truly understanding students' internal states. Therefore, the emotional component of this study was limited to the researchers' observations of students' learning environments and learning behaviors. The study's results remain valid because the researchers used a rigorous quasi-experimental design and a Rank Quade ANCOVA analysis, which appropriately controlled for differences in students' initial abilities. It is recommended that future studies incorporate more comprehensive affective evaluation instruments to enhance the cognitive analysis generated in this investigation.

■ CONCLUSION

This study concluded that combining the GASING method with the Quantum Learning approach significantly improved elementary school students' mathematical problem-solving abilities. Empirical results showed that the experimental group achieved a significant increase in scores, resulting in an effect size that reached the "Large" category. This study demonstrated that the systematic cognitive deconstruction technique, combined with effective learning environment management, yielded better results than the control class, which used the group discussion method and the CTL approach. The success of this synergy enabled students to learn more effectively by simplifying the content, while the positive classroom environment helped them develop a stable state of mental readiness.

It is recommended that teachers integrate the synergy of the GASING method and the Quantum Learning approach through the TAMAR framework into their mathematics lessons, as this practice will help build sustainable educational empowerment. However, they must remain aware of the actual challenges that arise during implementation. The main challenge that teachers must overcome is time constraints that prevent them from properly deconstructing the material and managing the classroom more efficiently than traditional teaching methods. The development of a community of practitioners and

Lesson Study among teachers will serve as a platform for teachers to exchange deconstructed GASING content modules. Interactive digital media empowers teachers to simplify the "Experience" and "Confirm" phases while maintaining the concrete essence of learning. For future researchers, future studies should conduct longitudinal investigations to assess how well this model maintains memory retention over time, and implement standardized affective assessment tools to build a complete understanding of the intervention's psychological effects on students' math anxiety and motivation.

■ DECLARATION ON THE USE OF GENERATIVE AI IN THE WRITING PROCESS

During the drafting process, the authors used the artificial intelligence (AI) tool Grammarly to improve sentence structure, correct grammatical inaccuracies, and ensure appropriate vocabulary. The implementation of the AI tool is designed to enhance the understanding and quality of the information disseminated. The authors confirm that all data interpretation, statistical evaluation, conclusions, and original contributions to the manuscript are solely the responsibility of the authors. The authors have carefully reviewed and refined all AI-generated content to ensure scientific rigor and contextual relevance to research in elementary education.

■ REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131–142. http://doi.org/10.1177/0013164485451012

Adu-Gyamfi, K., Chandler, K., & Thompson, A. (2025). Algebra story problem: The nature of students' obstacles. *School Science and Mathematics*, *125*(2), 140–153. https://doi.org/10.1111/ssm.12659

Andrade, C. (2021). The inconvenient truth about convenience and purposive samples. *Indian Journal of Psychological Medicine*, *43*(1), 86–88. https://doi.org/10.1177/0253717620977000

Axmedova, L. B. (2025). Modern approaches in preparing future primary school teachers: Integration of theory and practice. *International Journal of Pedagogics*, *5*(8), 17–19. https://doi.org/10.37547/ijp/volume05issue08-04

Badan Standar, Kurikulum, dan Asesmen Pendidikan. (2024). *Kajian Akademik Kurikulum Merdeka*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Brown, C. H., Hedeker, D., Gibbons, R. D., Duan, N., Almirall, D., Gallo, C., Burnett-Zeigler, I., Prado, G., Young, S. D., Valido, A., & Wyman, P. A. (2022). Accounting for context in randomized trials after assignment. *Prevention Science*, *23*(8), 1321–1332. https://doi.org/10.1007/s11121-022-01426-9

Callaman, R., & Palompon, D. (2026). Development of three-dimensional resiliency theory in solving mathematical problem. *Journal of Education and Learning*, *20*(1), 608–621. https://doi.org/10.11591/edulearn.v20i1.22738

Chen, Y. Q., & Zhang, S. X. (2025). Intrinsic preservation of plasticity in continual quantum learning. *arXiv preprint arXiv*: 2511.17228. https://doi.org/10.48550/arxiv.2511.17228

Chiofalo, M. L., Foti, C., Michelini, M., Santi, L., & Stefanel, A. (2022). Games for teaching/learning quantum mechanics: A pilot study with high-school students. *Education Sciences*, *12*(7), 1–34. https://doi.org/10.3390/educsci12070446

Cruz, C. R. O. D. (2025). *Estrategias de resolución de problemas matemáticos en* *estudiantes: una revisión sistemática* [Strategies for mathematical problem-solving in students: a systematic review]. *REVISTA INVECOM: Estudios Transdisciplinarios en Comunicación y Sociedad*, *5*(1), 1–10. https://doi.org/10.5281/zenodo.12659918

Csernicsko, I., Kuchinka, K., & Dorovtsi, A. (2025). Analysis of mathematical competence among students of Transcarpathian schools. *Herald of Khmelnytskyi National University*, *510*(4), 153–158. https://doi.org/10.31891/2307-5732-2025-355- 22

Dalughu, D., & Kurniawati, S. (2025). Effectiveness of GASING learning method on improving understanding concept of economics: A systematic literature review. *The International Conference on Sustainable Economics Management and Accounting (ICSEMA 2025) Proceedings*, (pp. 1830-1846). UPI Press. https://doi.org/10.32424/icsema.1.1.157

Devi, S. B., Jain, P., & Tyagi, G. (2024). Blended-learning-environment for mathematical skill acquisition among higher education learners using principal component analysis and structural equation modelling. *Educational Administration: Theory and Practice*, *30*(5), 5970–5977. https://doi.org/10.53555/kuey.v30i5.3888

Domu, I., & Mangelep, N. O. (2024). Factors that influence students' ability to solve mathematics story problems. *International Journal of Mathematics and Science Education*, *1*(3), 1–9. https://doi.org/10.62951/ijmse.v1i3.19

Engin, M. Ç., Gençdoðan, B., & Engin, A. O. (2024). A taxonomic approach on learning areas. *European Journal of Education and Pedagogy*, *5*(3), 8–14. https://doi.org/10.24018/ejedu.2024.5.3.583

Fan, C., & Zhang, D. (2017). Rank repeated measures analysis of covariance. *Communications in Statistics-Theory and Methods*, *46*(3), 1158–1183. https://doi.org/10.1080/03610926.2015.1014106

Faulkner, F., Breen, C., Prendergast, M., & Carr, M. (2021). Profiling mathematical procedural and problem-solving skills of undergraduate students following a new mathematics curriculum. *International Journal of Mathematical Education in Science and Technology, 54*(8), 1–30. https://doi.org/10.1080/0020739X.2021.1953625

George, D., & Mallery, P. (2019). *IBM SPSS Statistics 26 step by step: A simple guide and reference*. Routledge.

Gopalan, M., Rosinger, K. O., & Ahn, J. B. (2020). Use of quasi-experimental research designs in education research: Growth, promise, and challenges. *Review of Research in Education*, *44*(1), 218–243. https://doi.org/10.3102/0091732X20903302

Habib, M., Amjad, A. I., Aslam, S., Saleem, Z., & Saleem, A. (2024). Navigating math minds: Unveiling the impact of metacognitive strategies on 8th grade problem-solvers abilities. *International Electronic Journal of Elementary Education*, *17*(1), 135–144. https://doi.org/10.26822/iejee.2024.368

Hawthorne, B. S., Vella-Brodrick, D. A., & Hattie, J. (2019). Well-being as a cognitive load reducing agent: A review of the literature. *Frontiers in Education*, *4*(121), 1–11. https://doi.org/10.3389/feduc.2019.00121

Hendriana, H., Charitas, R. P. I., & Hidayat, W. (2019). The innovation of learning trajectory on multiplication operation for rural area students in Indonesia. *Journal* *on Mathematics Education*, *10*(3), 397–408. https://jme.ejournal.unsri.ac.id/index.php/jme/article/view/3802

Huang, Y. (2018). Influence of instructional design to manage intrinsic cognitive load on learning effectiveness. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(6), 2653–2668. https://doi.org/10.29333/ejmste/90264

Hurrell, D. (2021). Conceptual knowledge or procedural knowledge or conceptual knowledge and procedural knowledge: Why the conjunction is important to teachers. *Australian Journal of Teacher Education, 46*(2), 57–71. https://doi.org/10.14221/ajte.2021v46n2.4

Hussein, Y. F. (2022). Conceptual knowledge and its importance in teaching mathematics. *Middle Eastern Journal of Research in Education and Social Sciences*, *3*(1), 50–65. DOI: https://doi.org/ 10.47631/mejress.v3i1.445

Icuspit, M. J. (2025). Uncovering the multifaceted challenges and practical strategies in teaching elementary mathematics. *Divine Word International Journal of Management and Humanities*, *4*(3), 1959–1971. https://doi.org/10.62025/dwijmh.v4i3.173

Jordan, J., Wagner, J., Manthey, D. E., Wolff, M., Santen, S., & Cico, S. J. (2020). Optimizing lectures from a cognitive load perspective. *AEM Education and Training*, *4*(3), 306–312. https://doi.org/10.1002/aet2.10389

Julita, Darhim, & Herman, T. (2019). Capability of mathematical strategic thinking through quantum learning based on creative problem solving. *Journal of Physics: Conference Series*, *1320*(012099), 1–6. https://doi.org/10.1088/1742-6596/1320/1/012099

Kathayat, B. B. (2024). Metacognitive skills in mathematics learning: A systematic review of literature. *Journal of Musikot Campus*, *2*(1), 1–6. https://doi.org/10.3126/jmc.v2i1.70785

Kelly, K. (2022). Contextualizing curriculum for a multi-course classroom: A case study. *Curriculum and Teaching*, *37*(2), 39–53. https://doi.org/10.7459/ct/37.2.04

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2024). *Laporan hasil Asesmen Nasional Berbasis Komputer (ANBK) tahun 2023*. https://anbk.kemendikbud.go.id/

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2025). *Rapor Pendidikan 2024: Kota Singkawang*. Pusat Standar dan Kebijakan Pendidikan. https://anbk.kemendikbud.go.id/

Kim, H. (2020). Concreteness fading strategy: A promising and sustainable instructional model in mathematics classrooms. *Sustainability*, *12*(6), 1–18. https://doi.org/10.3390/su12062211

Kim, H., & Clasing-Manquian, P. (2023). Quasi-experimental methods: Principles and application in higher education research. In J. Huisman & M. Tight (Eds.), *Theory and method in higher education research: Vol. 9* (pp. 43–62). Emerald Publishing Limited. https://doi.org/10.1108/S2056-375220230000009003

Kim, T. K., & Park, J. H. (2019). More about the basic assumptions of t-test: normality and sample size. *Korean Journal of Anesthesiology*, *72*(4), 331–335. https://doi.org/10.4097/kja.d.18.00292

Martín-Requejo, K., González-Andrade, A., Álvarez-Bardon, A., & Santiago-Ramajo, S. (2023). *Implicación de las funciones ejecutivas, la inteligencia emocional y los hábitos y técnicas de estudio en la resolución de problemas matemáticos y* *el cálculo en la escuela primaria* [Involvement of executive functions, emotional intelligence, and study habits in mathematical problem-solving and calculation in elementary school]. *Revista de Psicodidáctica*, *28*(2), 145–152. https://doi.org/https://doi.org/10.1016/j.psicod.2023.06.003

Martinez-Padron, O. J. (2021). El afecto en la resolución de problemas de matemática. *Revista Caribeña de Investigación Educativa (RECIE)*, *5*(1), 86–100. https://doi.org/10.32541/recie.2021.v5i1.pp86-100

Maslihah, S., Waluya, S. B., Rochmad, & Suyitno, A. (2020). The role of mathematical literacy to improve high order thinking skills. *Journal of Physics: Conference Series*, *1539*(1), 1–6. https://doi.org/10.1088/1742-6596/1539/1/012085

Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review*, *36*(8), 1–25. https://doi.org/10.1007/s10648-023-09842-1

Memon, M. A., Thurasamy, R., Ting, H., & Cheah, J. H. (2025). Purposive sampling: A review and guidelines for quantitative research. *Journal of Applied Structural Equation Modeling*, *9*(1), 1–23. https://doi.org/10.47263/JASEM.9(1)01

Mukherjee, F. (2025). Exploring teaching methodologies that shape cognitive and psychological approaches to abstract mathematical learning. *The Social Science Review, a Multidisciplinary Journal*, *3*(5), 32–37. https://doi.org/10.70096/tssr.250305007

Nahar, S., Suhendri, Zailani, & Hardivizon. (2022). Improving students' collaboration thinking skill under the implementation of the quantum teaching model. *International Journal of Instruction*, *15*(3), 451–464. https://doi.org/10.29333/iji.2022.15325a

Ngu, B. H., & Phan, H. P. (2024). Instructional approach and acquisition of mathematical proficiency: Theoretical insights from learning by comparison and cognitive load theory. *Asian Journal for Mathematics Education*, *3*(3), 357–379. https://doi.org/10.1177/27527263241266765

Nnachi, A. B., Arinze, E. D., & Uchechukwu, A. J. (2024). Exploring the frontiers of data analysis: A comprehensive review. *INOSR Applied Sciences*, *12*(1), 62–68. https://doi.org/10.59298/inosras/2024/12.1.62680

OECD. (2023). *PISA 2022 Results (Volume I & II) – Country Notes: Indonesia*. OECD Publishing. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html

Olimova, M. (2025). The role of scaffolding in education: Enhancing learning through structured support. *Journal of Software Engineering and Applied Sciences*, *1*(3), 69–73. https://doi.org/10.5281/zenodo.15176151

Prabawanto, S. (2013). *Peningkatan kemampuan pemecahan masalah, komunikasi, dan self-efficacy matematis mahasiswa melalui pembelajaran dengan pendekatan metacognitive scaffolding* (Doctoral dissertation, Universitas Pendidikan Indonesia). UPI Repository. https://repository.upi.edu/3641/

Quade, D. (1967). Rank analysis of covariance. *Journal of the American Statistical Association*, *62*(320), 1187–1200. https://doi.org/10.2307/2283769

Rahman, M. M. (2019). 21st century skill "problem solving": Defining the concept. *Asian Journal of Interdisciplinary*

Research, *2*(1), 71–81. https://doi.org/10.34256/ajir1917

Raisinghani, K. A., & Kesur, B. N. (2024). Harnessing suggestopedia: Multisensory approaches for language learning and environmental literacy. *Asian Research Journal of Arts & Social Sciences*, *22*(10), 26–34. https://doi.org/10.9734/arjass/2024/v22i10582

Sardar, P. P. R. (2024). Twenty-first century skills for employability: a critical exploration. *Lex Localis-Journal of Local Self-Government*, *22*(S4), 12–19. https://doi.org/10.52152/64bv6q02

Sharma, L. R., & Jha, S. (2023). Applying major parametric tests using SPSS in research. *International Research Journal of MMC*, *4*(2), 85–97. https://doi.org/10.3126/irjmmc.v4i2.56017

Shimizu, Y. (2022). The content specificity and generality of the relationship between mathematical problem solving and affective factors. *Psych*, *4*(3), 574–588. https://doi.org/10.3390/psych4030044

Spybrook, J., Zhang, Q., Kelcey, B., & Dong, N. (2020). Learning from cluster randomized trials in education: An assessment of the capacity of studies to determine what works, for whom, and under what conditions. *Educational Evaluation and Policy Analysis*, *42*(3), 354–374. https://doi.org/10.3102/0162373720929018

Surya, Y., & Surya, M. A. (2026). *Gasing the fastest numeracy transformation ever demonstrated: Fondasi: filosofi, teori dan konteks (Vol. 1)*. Gasing Academy Press

Sweller, J. (2023). Cognitive load theory. In R. J. Tierney, F. Rizvi, & K. Ercikan. (Eds.), *International encyclopedia of education* (4th ed., pp. 127–134). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-818630-5.14020-5

Wang, H., Cruz, L., & Shank, M. (2020). The affect effect: Integrating student emotions into the design of engineering technology courses with optimization method. *IEEE Frontiers in Education Conference (FIE)* (pp. 1–8). IEEE. https://doi.org/10.1109/FIE44824.2020.9274279

William, S. K., & Maat, S. M. (2020). Understanding students' metacognition in mathematics problem solving: A systematic review. *International Journal of Academic Research in Progressive Education and Development*, *9*(3), 115–127. https://doi.org/10.6007/ijarped/v9-i3/7847

Yigiter, M. S. (2023). Does quantum learning model increase academic achievement? A meta-analysis study. *Cumhuriyet International Journal of Education*, *12*(3), 568–582. https://dx.doi.org/10.30703/cije.1216203

Yildiz, B., & Bayram, H. (2025). The effect of the quantum learning on students' academic achievements in social studies. *Kastamonu Education Journal*, *33*(3), 523–534. https://doi.org/10.24106/kefdergi.1748575