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The efficacy of sketching techniques as a visual scaffolding tool for enhancing mathematical word problem-solving among lower primary students

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Abstract

Mathematical word problem-solving remains a significant challenge for early primary students due to the abstract nature of linguistic information and cognitive load constraints. This study investigates the effectiveness of the Sketching Technique in enhancing the mathematical achievement of Year 2 students, with a specific focus on word-problem solving involving basic arithmetic operations. A quasi-experimental research design was employed involving 60 Year 2 students from a primary school in the Northeast District of Penang. The participants were divided into a treatment group (n=30) that used the Sketching Technique and a control group (n=30) that followed conventional teaching methods. The research instrument was an achievement test consisting of 10 word-problem questions, with a total score of 10 marks. The test's internal consistency reliability was acceptable (Kuder-Richardson Formula 20 = 0.81). Data were collected using pre-test and post-test instruments and analyzed using paired and independent-samples t-tests. Findings revealed a significant improvement in the treatment group, with the mean score increasing markedly from 2.33 on the pre-test to 9.53 on the post-test. Conversely, the control group showed minimal improvement, with mean scores rising from 2.30 to only 2.90. Statistical analysis confirmed a significant difference between the two groups, with the treatment group demonstrating more consistent performance as evidenced by a reduction in standard deviation from 1.73 to 0.51. Furthermore, the effect size (Cohen's d) was calculated to be 5.65, indicating very large practical significance of the intervention. These results suggest that integrating visual-based pedagogical innovations is crucial for improving numeracy outcomes and fostering critical thinking in early primary education.

Keywords:
Cognitive load theory, Lower primary education, Sketching technique, Visual representation, Word problem-solving

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1. INTRODUCTION

Math skills in early school years are very important, especially for solving problems (Özcan & Doğan, 2018; Setambah et al., 2024; Wahyuni et al., 2025). Problem-solving is a key part of the math curriculum in Malaysia and other countries. But many primary school students still find it hard to solve math problems. This happens because they haven't fully mastered problem-solving skills or don't really understand them (Ekawati et al., 2026; Harisman et al., 2026; Murtafiah et al., 2023; Suprotun & Suparman, 2019). This also indirectly creates students who are less able to relate the mathematical knowledge they receive to real reality, which causes students' studies and lives to be separated into two different directions. Furthermore, mathematical problem-solving skills are a skill that is difficult for students to master due to low exposure to mathematical questions in the form of mathematical problems (Liu et al., 2025). As a result, students struggle to connect what they learn in math class to real life. This creates a gap between their studies and daily experiences. Also, students rarely get exposed to math problems, which makes it even harder for them to learn

Malaysian primary school students face numeracy problems in solving word problems (Gholami, 2023; Wei et al., 2025). This happens when teachers not only focus too much on the method of memorizing formulas such as the sifir box to solve Mathematics problems, but students are also stressed on the method of memorizing formulas and algorithms (Nasution et al., 2025). Previous research supports that students need to think mathematically to solve problems involving basic mathematical operations in primary schools (McNeil et al., 2025). Based on that, students not only need to master basic skills but must also be able to apply these skills in daily life which can be referred to as problem solving. Therefore, educators need to play a role as agents of change by understanding students' difficulties in solving word problems and subsequently guiding them to understand and solve mathematical problems more effectively (DeDecker et al., 2023; Iilonga & Ogbonnaya, 2023; Maharani et al., 2019).

Therefore, students should be exposed to routine and non-routine problem-solving questions in verse more regularly and in line with the application of effective and quality teaching techniques and activities. This will ensure the effectiveness of applying these skills in primary school students. Therefore, teaching techniques should be modified and developed to train students to master problem-solving skills to improve their Mathematics achievement and face real-world challenges (Nasir et al., 2021).

The selection of the Sketching Technique as the intervention in this study is grounded in three complementary theoretical perspectives from mathematics education literature. First, Cognitive Load Theory (Sweller, 1988) posits that novice learners, particularly Year 2 students, suffer from overload when processing both linguistic information and numerical operations simultaneously. Sketching reduces extraneous cognitive load by externalizing problem information into visual-spatial formats (Hegarty & Kozhevnikov, 1999). Second, Dual Coding Theory (Paivio, 1991) provides justification, as it argues that information processed through both verbal and visual channels enhances memory and comprehension. Word problems inherently activate verbal coding; sketching adds the missing visual code. Third, and most critically, Schema-Based Instruction (SBI) literature (Fuchs et al., 2004; Jitendra et al., 2015) demonstrates that students with word problem-solving difficulties benefit from identifying underlying problem structures (e.g., combine, compare, change) through visual diagrams. The Sketching Technique operationalizes SBI by guiding students to draw concrete representations that map directly onto these semantic schemas. Unlike conventional rote methods, this visual approach aligns with van Garderen's (2007) finding that successful problem solvers spontaneously use drawings to organize information, while struggling solvers do not. Thus, the Sketching Technique is not merely an engaging activity but a theoretically justified cognitive scaffold designed to bridge the gap between text comprehension and mathematical operation selection.

The Sketch technique was introduced in the context of the study. The "sketch" technique has been proven to improve students' ability to interpret and represent mathematical problems, which is a critical component in solving verse problems (Ziadat, 2022). The Sketch technique in this study refers to the method of sketching or drawing what comes to the mind of students while reading a Mathematical verse problem Cartwright (2024). Individuals who can visualize the thought process or situation in the question are a technique in solving using visualization. Through visuals, individuals can also benefit from visual images available in the form of photos, diagrams, sketches and tables in their efforts to understand the Mathematical issue that needs to be solved. This is in line with Si and Huan (2024), which found that children can understand arithmetic issues more completely when they can create a visual picture of the situation in the problem. Figure 1 illustrates an example of the use of the Sketch technique implemented by students. This technique allows students to visualize the problem, describe the solution, and model mathematically, although it may take longer for illustrations. Visualization through this sketch technique can make it easier for students to understand the steps of solving problems, especially in story questions, thus increasing their ability in solving mathematical problems (Gansemer-Topf et al., 2021; Lewis et al., 2023).

Figure 1 is an example of a sketch that was made by students to answer the basic operations hat problem-solving questions. The application of such visualization techniques can activate learning actively and efficiently through exploration, experimentation, and observation (Kortemeyer, 2023). This study adapted this approach in the hope of improving students' mathematical representation abilities, which are empirically proven to be low in solving mathematical problems (Sartika et al., 2019). Previous research has also shown that the use of visual learning media can improve students' abilities in solving mathematical problems, thinking creatively, and reasoning (Hahn & Klein, 2023). This is supported by study findings that show that visualization-based teaching can significantly improve problem-solving skills (Lane, 2017).

In this study, the Sketch Technique was implemented through a structured four-step procedure adapted from van Garderen (2007) and Ziadat (2022). First, students read the word problem twice and underlined key information such as numbers and action words (e.g., "altogether," "left"). Second, students drew a simple sketch representing the problem situation using basic shapes such as circles, squares, or stick figures; they were taught that artistic ability was not required. Third, students labeled their sketches with numbers and operation symbols to visually identify whether addition or subtraction was needed. Fourth, students wrote the mathematical equation based on their sketch, calculated the answer, and verified their solution against the visual representation. The technique was used across six instructional sessions (40 minutes each), with students practicing sketching on 3-4 word problems per session. The teacher provided scaffolding using a gradual release model: direct modeling in the first two sessions ("I do"), guided practice with peer collaboration in the next two sessions ("We do"), and independent sketching in the final two sessions ("You do"). This structured implementation ensured that students in the treatment group received consistent and explicit instruction in the use of sketching as a problem-solving strategy.

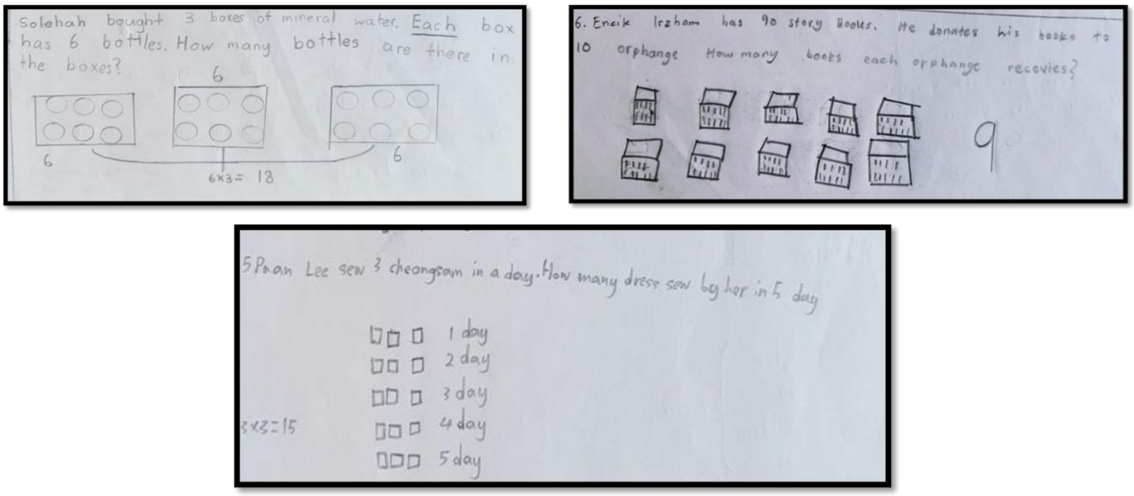

Figure 1. Student using sketch technique

Therefore, this study focuses on the effectiveness of using sketch techniques in improving students' mathematics achievement, especially in the context of solving word problems (Morden-Snipper et al., 2015) for the topic of basic operations only. Previous studies have also proven that visualization plays an important role in improving students' understanding and performance in solving word problems. Therefore, the study aims to test the effect of this sketch technique on the achievement of year 2 students in the aspect of problem solving focusing on the topic of basic operations only.

2. METHOD

This study used a quasi-experimental design with a quantitative approach to identify the relationship between independent variables and dependent variables. This design was chosen because of its suitability in collecting descriptive and statistical data to test the effectiveness of interventions in school settings (Chua, 2011). A total of 60 Year 2 students were selected as respondents, of which 30 students were placed in the treatment group who received instruction using the Sketch Technique, while the other 30 were in the control group who were taught using the traditional method based on textbooks. To control for potential confounding variables related to teacher competency and instructional style, the researcher personally delivered all lessons to both the treatment and control groups. The researcher taught both groups using an identical schedule (six sessions, 40 minutes each) and maintained consistent levels of enthusiasm, commitment, and instructional time across both groups. The only difference between the groups was the instructional technique employed. This design can be illustrated in Figure 2.

The intervention was conducted over three weeks with two 40-minute sessions per week, totaling six sessions (240 minutes). The same teacher taught both groups. For the treatment group, each session followed a four-step sketching procedure: (1) underline key information (read) ; (2) draw simple shapes to represent the problem (sketch); (3) Label – add numbers and identify + or -; (4) write the equation and verify with the sketch (Draw. The first two sessions involved teacher modeling ("I do"), sessions three and four involved guided practice ("We do"), and sessions five and six involved independent sketching ("You do"). The control group followed the same session structure but used conventional keyword-based instruction (e.g., "altogether" means add) without sketching.

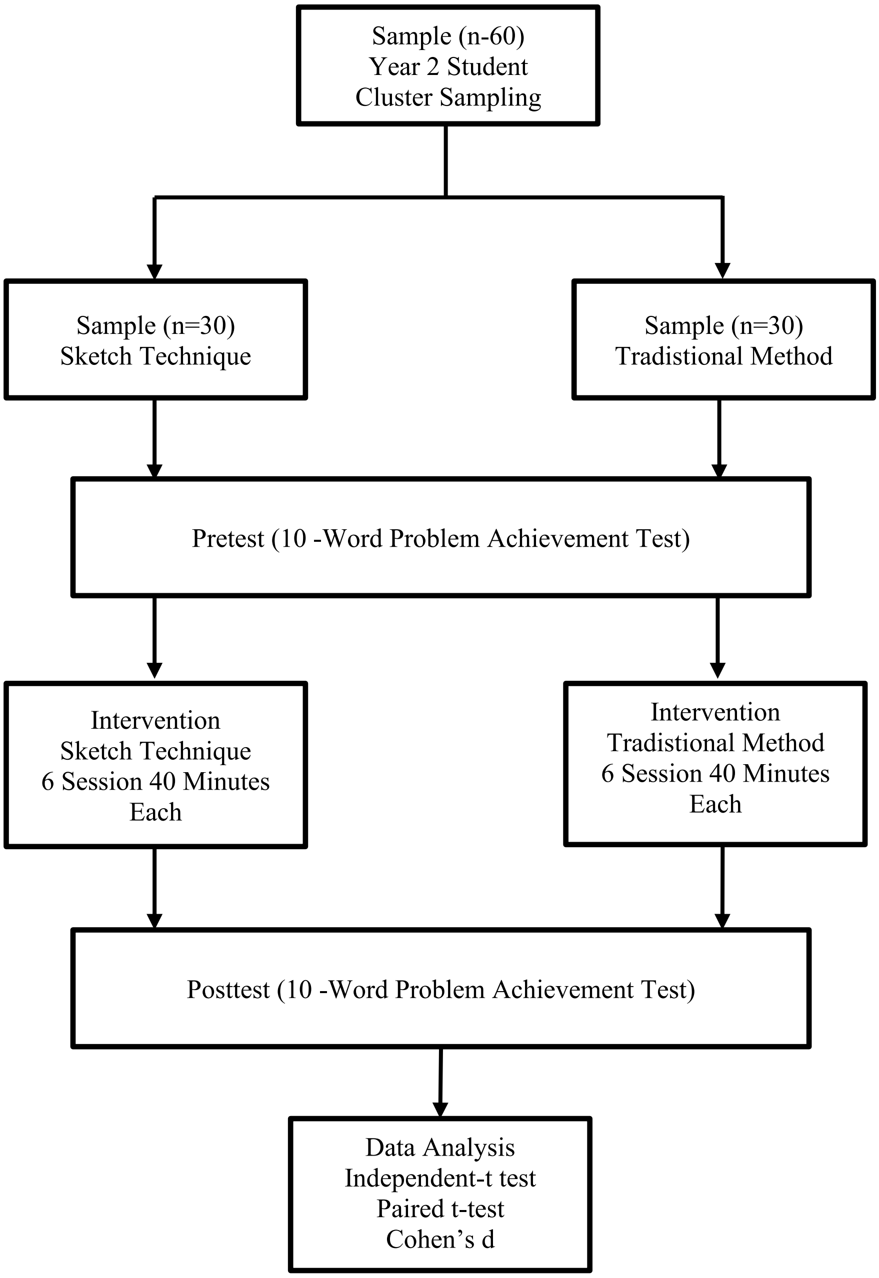

Figure 2. Experimental process and numbers of sample

In terms of population and sample, this study was conducted at a national primary school in the Timur Laut district, Penang. The researcher used cluster sampling to ensure that the selected sample truly represented the target population (Mohd Yusof, 2005). The selection process involved determining the location and employing a cluster sampling technique, where two intact Year 2 classes were randomly selected from the school. One randomly selected class was assigned as the treatment group, and the other randomly selected class served as the control group. This step was important to ensure that a fair comparison could be made between the group that received the sketch technique and the group that used the conventional method.

The main instrument used in this study was an achievement test consisting of a pre-test and a post-test. According to Creswell and Creswell (2018), the use of pre-test and post-test is very appropriate in quasi-experimental studies to measure the extent to which students have mastered a topic. The pre-test was conducted to identify the initial level of students in solving sentence problems before the intervention, while the post-test was given after the introduction of the Sketch Technique. Both tests were equivalent in terms of question form, time, and scoring scheme. To establish content validity, the test items were developed based on the Year 2 Mathematics textbook and the Malaysia Standard Curriculum and Assessment Document (SCAD). The items were reviewed and validated by two experienced Mathematics teachers and one content expert from the university. A pilot study was conducted with 30 Year 2 students from a different school within the same district who possessed similar characteristics to the actual sample. The pilot test results were analyzed using the Kuder-Richardson formula (KR-20), yielding a reliability coefficient of 0.81, indicating high internal consistency. Therefore, the instrument was considered valid and reliable for measuring students' mathematical achievement in word problem-solving.

To analyze the data, paired sample t-tests and independent t-tests were used to see significant differences between the mean scores for the two groups and the mean scores of the pre-test and post-test. The summary of the study implementation is illustrated in Figure 3.

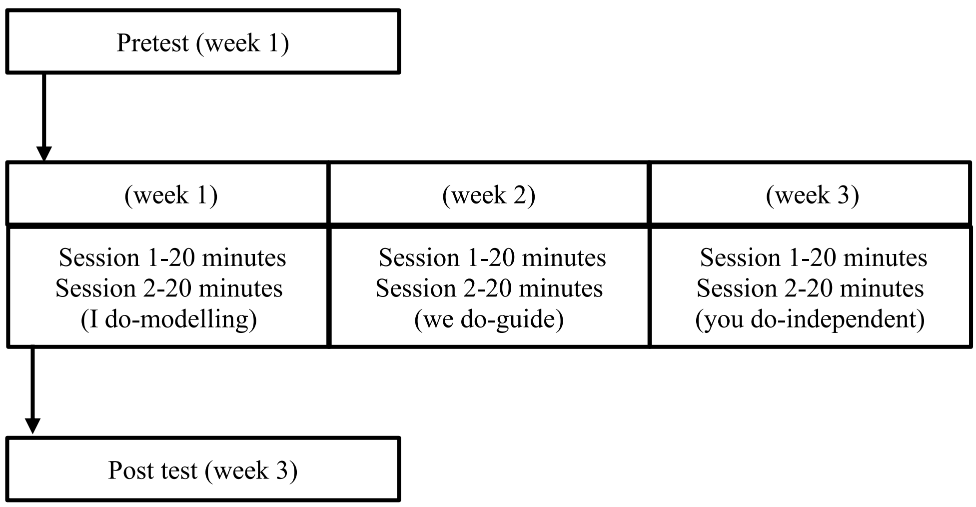

Figure 3. Summarize of study implementation

3. RESULTS AND DISCUSSION

3.1. Results

Data analysis was conducted to assess the effect of the Sketch Technique on the mathematics achievement of Year 2 students. Figure 4 shows the comparison of mean scores between the Control Group and the Treatment Group.

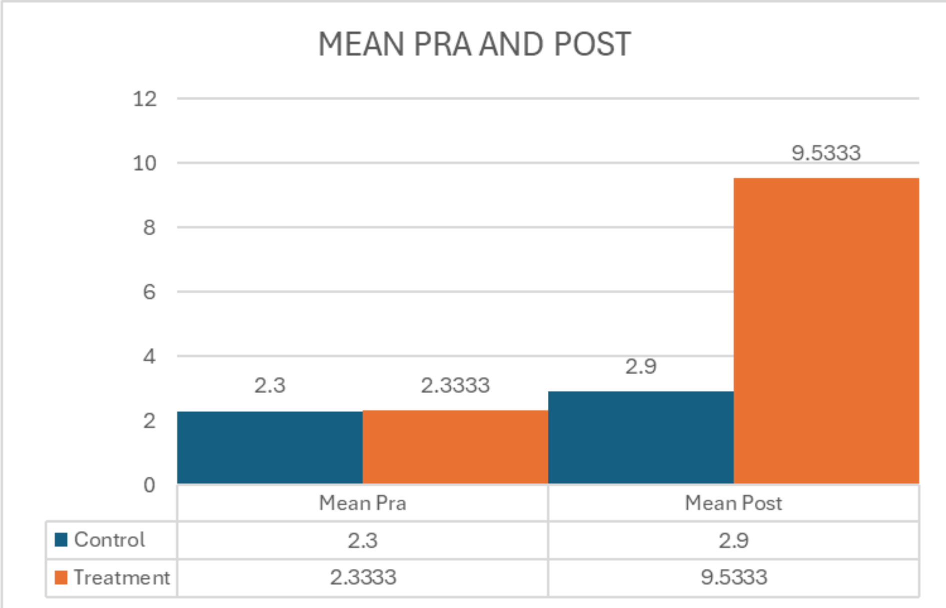

Figure 4. Mean pra and post control and experiment group

An independent samples t-test was conducted to compare the pretest and posttest scores between the control and treatment groups. For the pretest, there was no significant difference between the control group ($M = 2.30$, $SD = 1.60$) and the treatment group ($M = 2.33$, $SD = 1.73$); $t(58) = -0.077$, $p = 0.939$, 95% CI [-0.892, 0.826]. This confirms that both groups had homogeneous mathematical achievement levels prior to the intervention.

Following the intervention, the treatment group demonstrated a substantial increase in achievement compared to the control group. The independent samples t-test revealed a statistically significant difference between the control group ($M = 2.90$, $SD = 1.27$) and the treatment group ($M = 9.53$, $SD = 0.51$); $t(58) = -25.85$, $p < 0.001$, 95% CI [-7.147, -6.119]. The mean difference of -6.633 ($SE = 0.257$) indicates that the treatment group scored 6.63 points higher than the control group on average. Furthermore, the standard deviation of the treatment group decreased from 1.73 in the pretest to 0.51 in the posttest, indicating more consistent performance and a reduction in the achievement gap among students in the treatment group.

Paired-samples t-tests were conducted to examine the effectiveness of the intervention within each group. For the treatment group, there was a statistically significant increase from pre-test ($M = 2.33$, $SD = 1.73$) to post-test ($M = 9.53$, $SD = 0.51$); $t(29) = -22.14$, $p < 0.001$. The effect size was very large, Cohen's $d = 4.04$. For the control group, the increase from pre-test ($M = 2.30$, $SD = 1.60$) to post-test ($M = 2.90$, $SD = 1.27$) was also statistically significant but substantially smaller; $t(29) = -2.18$, $p = 0.037$, Cohen's $d = 0.40$. These results confirm that while both groups showed improvement, the Sketch Technique produced a substantially larger and more meaningful effect (d = 4.04) compared to conventional instruction (d = 0.40).

Several factors may explain the exceptionally large gains (pre-test 2.33 to post-test 9.53, Cohen's d = 5.65). First, the low pre-test scores created substantial room for improvement. Second, the Sketch Technique directly addressed the cognitive bottleneck of Year 2 students (Piaget's concrete operational stage) by externalizing abstract language into concrete visuals, reducing working memory load. Third, the structured scaffolding (I Do, We Do, You Do) ensured students mastered the strategy before working independently. Fourth, the novelty of drawing likely increased student engagement and motivation compared to conventional worksheets. Fifth, the same teacher delivered both interventions, eliminating teacher-related confounding variables. While these gains are exceptionally large, it should be noted that the low baseline performance and short intervention duration (three weeks) may limit generalizability to populations with higher initial ability or longer intervention periods.

3.2. Discussion

The sharp increase in this treatment group occurred because the Sketch Technique acted as a cognitive "bridge". Year 2 students are at the stage of concrete operational development (Piaget, 1976), where they have difficulty processing abstract sentences. By sketching situations (for example, drawing 3 apples plus 2 more), students can: (1) Translate Language to Visual: Convert long sentences into an easily visible form; (2) Identify Operations: Through sketches, students can more easily see whether they need to add or subtract; and (3) Improve Focus: The drawing process forces students to read the question carefully to ensure that their sketches are accurate to the requirements of the question (Musrikah et al., 2023).

The substantial improvement in the treatment group's performance may be explained by the cognitive scaffolding provided by the Sketching Technique. Although this study did not directly measure cognitive processes, the reduction in standard deviation from 1.73 to 0.51 suggests that students demonstrated more consistent performance, which could indicate improved comprehension of the problem-solving tasks. First, the technique acts as a bridge for linguistic-to-visual decoding, where students translate abstract word problems into concrete mental models. As seen in Figure 1, the student successfully transformed the textual phrase "3 boxes" and "6 bottles" into identifiable geometric shapes, which mitigated the linguistic interference often associated with complex word problems. This process aligns with Cognitive Load Theory, as the sketch serves as an external memory aid that reduces the strain on a student's working memory. By offloading the need to mentally visualize the entire scenario, students can allocate their remaining cognitive resources toward identifying the correct mathematical operation, such as multiplication (\$6 \times 3\$), rather than struggling with text comprehension.

Furthermore, the Sketching Technique supports students' development during the concrete operational stage, as proposed by Piaget (1976), where learners require physical or visual representations to process abstract concepts. The visual evidence in Figure 1 demonstrates that the student was able to explicitly model the relationship between "groups" and "members," a fundamental component of mathematical thinking. This visual scaffolding not only clarifies the problem structure but also enables self-validation. The students can cross-check their sketches against the problem's requirements to ensure accuracy before arriving at a solution. Ultimately, the transition from traditional rote memorization to this active visualization strategy fosters a deeper conceptual understanding, allowing students to bridge the gap between formal mathematics and real-world application.

This study is in line with the studies by Morden-Snipper et al. (2015), and Hahn and Klein (2023), which emphasized the importance of visualization in arithmetic. The control group's failure to achieve high scores indicates that the "talk and chalk" approach, or simply referring to the textbook, is no longer sufficient for complex sentence-problem-solving questions. The Sketch Technique not only improves achievement but also appears to promote more active student engagement during mathematics lessons, as observed anecdotally during the intervention. However, this study did not directly measure student enjoyment or engagement. Future research should include validated instruments to assess affective outcomes such as motivation, attitudes toward mathematics, and perceived enjoyment.

The effectiveness of the Sketch Technique in this study can be explained through Cognitive Load Theory. Sentence problem-solving questions in Year 2 Mathematics often burden students' working memory because they need to read, understand language, and calculate simultaneously. This cognitive load can be reduced through the use of visual representations. The Sketch Technique functions as a "scaffolding" tool that allows students to transfer information from complex text to simple sketches. When students draw question situations, they are actually performing a decoding process that makes it easier for the brain to process the required mathematical operations without being confused by linguistic interference (the words in the question).

The findings of this study also answer the issue raised by Varatharaju and Setambah (2023), and Asmara et al. (2026) regarding numeracy problems among Malaysian students. Often, students fail not because they do not know how to count (basic operations), but because they do not understand "what needs to be counted". The use of sketching techniques gives confidence to students with low language literacy levels. For example, students who have difficulty understanding the words "difference" or "remainder" can see the concept physically through block comparison sketches or diagrams. Overall, this study provides evidence suggesting that the use of the Sketch Technique has a positive effect on the mathematics achievement of Year 2 students, particularly in problem-solving skills, within the context of this study.

The significant difference between the treatment and control groups (Mean 9.53 compared to 2.90) proves that the algorithmic memorization strategy practiced in the traditional method is no longer relevant for questions in the form of sentence problems (Gansemer-Topf et al., 2021). The control group that only relies on textbooks and static formulas was found to be stuck when faced with non-routine questions. On the other hand, the Sketch Technique encourages active mathematical thinking. Students no longer wait for the teacher to provide a solution, but instead explore solutions through their own sketches. This is in line with Kaur and Yeap (2009) findings that students need to "think mathematically" to succeed in this subject. An interesting finding in this study is the decrease in the Standard Deviation (SD) value for the treatment group from 1.73 to 0.51. This decrease is very significant because it shows that this technique not only helps excellent students, but also helps the weakest students to reach a level that is almost the same as their peers (performance becomes more consistent/stable). The Sketch technique reduces "guessing" in Mathematics. If previously students simply guessed the operation (+ or -), sketches force them to understand the logic behind the question, thus stabilizing the achievement of the entire class.

4. CONCLUSION

Overall, this study has successfully proven that the use of Sketch Technique has a very positive and significant impact on the achievement of Mathematics of Year 2 students, especially in problem-solving skills. Comparison of performance between groups shows that students exposed to the sketch technique experienced a drastic increase in mean score from 2.33 to 9.53, compared to the control group which only showed a minimal increase through the traditional method. This finding confirms that visualization functions as an effective cognitive bridge to help students translate abstract sentences into concrete forms that are easier to understand. This is in line with the cognitive development level of level one students who need visual support to process complex information and reduce the burden of working memory when completing basic mathematical operations.

The implications of this study show that the transition from formula memorization methods to more creative problem-solving techniques is very necessary in today's education system. The failure of traditional methods to significantly improve achievement proves that students need more interactive strategies to connect text language with numeracy concepts. Therefore, educators are advised to consistently integrate sketch techniques in teaching and learning (T&L) sessions to build confidence and critical thinking skills among students.

However, several limitations should be acknowledged. First, the researcher taught both groups, which may have introduced bias due to greater enthusiasm for the Sketch Technique. Second, the quasi-experimental design using intact classes without individual random assignment limits causal inferences. Third, the study was conducted in a single school with a sample size of 60 students, which may limit generalizability. Future research should employ multiple instructors, blinded designs, and larger sample sizes across multiple schools. In conclusion, the Sketch Technique not only succeeded in improving students' achievement grades, but it is also a pedagogical innovation that is able to bridge the learning gap and provide students with a strong mathematical foundation to face real-world challenges.

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Declarations

Author Contribution : SHZ: Conceptualization, Funding acquisition, and Writing - original draft; MABS: Conceptualization, Methodology, Validation, and Writing - original draft; E: Conceptualization, and Investigation; AA: Formal analysis; MS: Writing - review & editing; HH: Writing - review & editing.

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REFERENCES

Asmara, A. S., Yusuf, Y., Prawiyogi, A. G., Zonyfar, C., Alhamssyah, M. A., & Alfarid, M. N. (2026). Profiling numeracy literacy among ninth-grade students: Empirical evidence from junior secondary education. *Infinity Journal*, *15*(1), 291–318. https://doi.org/10.22460/infinity.v15i1.p291-318

Cartwright, K. (2024). Interpreting young children's multiplicative strategies through their drawn representations. *Mathematics Education Research Journal*, *36*(2), 367–397. https://doi.org/10.1007/s13394-023-00450-4

Chua, Y. P. (2011). *Kaedah dan statistik penyelidikan: Kaedah penyelidikan*. McGraw-Hill Education.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage publications.

DeDecker, S., Vale, J., Gordon, K., & Clemmer, R. (2023). STEM student perceptions of problem-solving skill development and the importance of memorization in problem-solving courses. In *Proceedings of the Canadian Engineering Education Association (CEEA)*, (pp. 149). https://doi.org/10.24908/pceea.2023.17125

Ekawati, R., Fitriana, L. D., Prahmana, R. C. I., Mahdiannur, M. A., Nisa, K., & Sa'diyah, M. (2026). The dynamics of behavioral pattern in collaborative problem-solving among Indonesian preservice mathematics teachers. *Infinity Journal*, *15*(1), 115–132. https://doi.org/10.22460/infinity.v15i1.p115-132

Fuchs, L. S., Fuchs, D., & Prentice, K. (2004). Responsiveness to mathematical problem-solving instruction. *Journal of Learning Disabilities*, *37*(4), 293–306. https://doi.org/10.1177/00222194040370040201

Gansemer-Topf, A. M., Paepcke-Hjeltness, V., Russell, A. E., & Schiltz, J. (2021). "Drawing" your own conclusions: Sketchnoting as a pedagogical tool for teaching ecology. *Innovative Higher Education*, *46*(3), 303–319. https://doi.org/10.1007/s10755-020-09542-6

Gholami, H. (2023). Performance of Malaysian foundation level students in mathematical problem solving as well as gender comparison. *Mathematics Teaching Research Journal*, *15*(2), 104–120.

Hahn, L., & Klein, P. (2023). Analysis of eye movements to study drawing in the context of vector fields. *Frontiers in Education*, *8*, 1162281. https://doi.org/10.3389/feduc.2023.1162281

Harisman, Y., Hafizatunnisa, H., Asra, A., Armiati, A., Suherman, S., Adnan, M., Purnomo, Y. W., Sumarni, P., & Syaputra, H. (2026). An analysis of Indonesian and Malaysian postgraduate students' mathematical problem-solving behavior using research skill development framework. *Infinity Journal*, *15*(2), 571–594. https://doi.org/10.22460/infinity.v15i2.p571-594

Hegarty, M., & Kozhevnikov, M. (1999). Types of visual–spatial representations and mathematical problem solving. *Journal of educational psychology*, *91*(4), 684–689. https://doi.org/10.1037/0022-0663.91.4.684

Iilonga, H. K., & Ogbonnaya, U. I. (2023). Grade 10 Namibian learners' problem-solving skills in algebraic word problems. *Infinity Journal*, *12*(2), 275–290. https://doi.org/10.22460/infinity.v12i2.p275-290

Jitendra, A. K., Petersen-Brown, S., Lein, A. E., Zaslofsky, A. F., Kunkel, A. K., Jung, P.-G., & Egan, A. M. (2015). Teaching mathematical word problem solving: The quality of evidence for strategy instruction priming the problem structure. *Journal of Learning Disabilities*, *48*(1), 51–72. https://doi.org/10.1177/0022219413487408

Kaur, B., & Yeap, B. H. (2009). Mathematical problem solving in Singapore schools. In B. Kaur, B. H. Yeap, & M. Kapur (Eds.), *Mathematical problem solving: Yearbook 2009* (pp. 3–13). Association of Mathematics Educators. https://doi.org/10.1142/7335

Kortemeyer, G. (2023). Writing virtual reality teaching resources. *The Physics Teacher*, *61*(2), 107–109. https://doi.org/10.1119/5.0067963

Lane, D. (2017). Drawing and sketching: Understanding the complexity of paper-pencil interactions within technology education. In M. de Vries (Ed.), *Handbook of Technology Education* (pp. 1–18). Springer. https://doi.org/10.1007/978-3-319-38889-2_32-1

Lewis, M., Sturdee, M., Hoang, T., Gamboa, M., & Jain, P. (2023). SketCHI 5.0: Diversity & accessibility at the core of sketching in HCI. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, (pp. 1–3). https://doi.org/10.1145/3544549.3583182

Liu, J., Keane, T., Sun, D., Yang, Y., & Yang, Y. (2025). Design and evaluation of ChatGPT-MWPS: An AI-enhanced learning system for improving primary students' mathematical word problem solving. *Smart learning environments*, *12*(1), 68. https://doi.org/10.1186/s40561-025-00419-9

Maharani, S., Kholid, M. N., Pradana, L. N., & Nusantara, T. (2019). Problem solving in the context of computational thinking. *Infinity Journal*, *8*(2), 109–116. https://doi.org/10.22460/infinity.v8i2.p109-116

McNeil, N. M., Jordan, N. C., Viegut, A. A., & Ansari, D. (2025). What the science of learning teaches us about arithmetic fluency. *Psychological Science in the Public Interest*, *26*(1), 10–57. https://doi.org/10.1177/15291006241287726

Mohd Yusof, K. (2005). *Kaedah penyelidikan pendidikan*. Prentice Hall.

Morden-Snipper, D. R., Dai, T., Booth, J. L., Chang, B. L., Cromley, J. G., & Newcombe, N. S. (2015). Cognitive factors and representation strategies in sketching math diagrams. In *Proceedings of the 37th Annual Meeting of the Cognitive Science Society*, (pp. 1637–1642).

Murtafiah, W., Lestari, N. D. S., Yahya, F. H., Apriandi, D., & Suprapto, E. (2023). How do students' decision-making ability in solving open-ended problems? *Infinity Journal*, *12*(1), 133–150. https://doi.org/10.22460/infinity.v12i1.p133-150

Musrikah, M., Asmarani, D., & Handoko, A. I. (2023). Karakteristik representasi visual, verbal, dan simbolis matematis mahasiswa calon guru sekolah dasar [Characteristics of visual, verbal, and symbolic mathematical representations of prospective elementary school teachers]. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *12*(3), 2847–2861. https://doi.org/10.24127/ajpm.v12i3.6693

Nasir, N. A. M., Singh, P., Narayanan, G., Han, C. T., Rasid, N. S., & Hoon, T. S. (2021). An analysis of undergraduate students ability in solving non-routine problems. *Review of International Geographical Education Online*, *11*(4), 861–872.

Nasution, S. H., Jupri, A., & Dasari, D. (2025). Students' anxiety level in learning mathematics and its influencing factors. In *The 5th International Conference on Mathematics and its Applications (ICoMathApp) 2024: Innovations in Mathematics and Mathematics Education for Sustainable Futures*, (Vol. 3446, pp. 030044). https://doi.org/10.1063/5.0309365

Özcan, Z. Ç., & Doğan, H. (2018). A longitudinal study of early math skills, reading comprehension and mathematical problem solving. *Pegem Eğitim ve Öğretim Dergisi*, *8*(1), 1–18. https://doi.org/10.14527/pegegog.2018.001

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology / Revue canadienne de psychologie*, *45*(3), 255–287. https://doi.org/10.1037/h0084295

Piaget, J. (1976). Piaget's Theory. In B. Inhelder, H. H. Chipman, & C. Zwingmann (Eds.), *Piaget and His School: A Reader in Developmental Psychology* (pp. 11–23). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-46323-5_2

Sartika, D., Mutmainna, A. A. A., Abdullah, H., & Tawil, M. (2019). Preliminary research on prospective teacher's ability in understanding the physics problems by sketching *The 8th National Physics Seminar 2019*,

Setambah, M. A. B., Adnan, M., Zaini, S. H., Mujiasih, M., Hidayat, R., Ibrahim, M. A., & Hanazono, H. (2024). Impact of "Donkey", "Snap" dan "King" (DSK) non-digital gamification cards on fourth-grade students' math performance in fractions. *Infinity Journal*, *13*(1), 175–196. https://doi.org/10.22460/infinity.v13i1.p175-196

Si, L. S., & Huan, C. (2024). Effectiveness of visualisation integrated problem solving approach on improving grade three Malaysian students' arithmetic word problem solving ability. *International Journal of Academic Research in Progressive Education and Development*, *13*(4), 3153–3162. https://doi.org/10.6007/IJARPED/v13-i4/22953

Suprotun, S., & Suparman, S. (2019). Development learning design lift material flap with character education to improve problem solving abilities. *International Journal of Scientific and Technology Research*, *8*(12), 2806–2810.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*(2), 257–285. https://doi.org/10.1016/0364-0213(88)90023-7

van Garderen, D. (2007). Teaching students with LD to use diagrams to solve mathematical word problems. *Journal of Learning Disabilities*, *40*(6), 540–553. https://doi.org/10.1177/00222194070400060501

Varatharaju, S., & Setambah, M. A. B. (2023). Perlaksanaan kbat dengan penggunaan kaedah jadual dalam penyelesaian masalah matematik tahun empat [Implementation of HOTS using the table method in year four mathematical problems]. *Jurnal Pendidikan Sains Dan Matematik Malaysia*, *13*(1), 22–30.

Wahyuni, R., Suwanto, F. R., Sthephani, A., & Ahyan, S. (2025). Students' obstacles in solving algebra form problems viewed from mathematical problem-solving ability. *Infinity Journal*, *14*(3), 587–606. https://doi.org/10.22460/infinity.v14i3.p587-606

Wei, L. Y., Gabda, D., Ping, N. P. T., & Mun, H. C. (2025). Challenges and opportunities: A comparison of PISA 2022 mathematics performance in Malaysia and other ASEAN countries. *Mathematics Teaching Research Journal*, *17*(3), 201–222.

Ziadat, A. H. (2022). Sketchnote and working memory to improve mathematical word problem solving among children with dyscalculia. *International Journal of Instruction*, *15*(1), 509–526. https://doi.org/10.29333/iji.2022.15129a