

Enhancing decimal problems solving of sixth grade students: Using the bar model technique

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ABSTRACT

Due to the problem of PISA test results showing mathematics scores below the average, along with teaching and learning issues where students still struggle with solving problems involving decimals then this research aims to achieve two primary objectives: (1) To compare students' performance on decimal problems before and after implementing the bar model technique. (2) To examine the effectiveness of the bar model technique in enhancing students' achievement in solving decimal problems, with a criterion of 70 out of 70. The sample for this study was specifically selected from a group of 29 students in the class. The students were then given a pre-test, and those who scored below 65% of the total score were selected. As a result, 15 students who struggled with solving decimal problems were identified. This research follows a mixed-methods approach, including qualitative data collection. Six students were randomly selected for interviews as the target group for qualitative analysis. The results revealed the following: (1) The post-test scores of the students were significantly higher than their pre-test scores at a significance level of 0.05. The post-test average score was 16.73, while the pre-test average score was 11.20. The discrepancy between the pre- and post-test scores was 5.53. (2) The effectiveness of the bar model technique on students' achievement in solving decimal problems (E1 and E2) was found to be 79.77 percent and 83.65 percent, respectively, surpassing the specified threshold. Interviews with the target students indicated a clear increase in average scores. Students commented that the bar model improved their understanding of individual phrases, enabling them to analyze and represent them symbolically, leading to easier problem-solving. This research provides an alternative teaching method for mathematics. Recommendations for future research could explore the effects of the bar model on students with diverse learning styles or examine how students adapt this method across different cultural settings.

Keywords: decimal problem, bar model technique, achievement, effectiveness

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INTRODUCTION

Mathematics holds profound significance in shaping human thought, fostering creativity, promoting rational thinking, effective problem-solving, and systematic planning. It establishes a comprehensive framework for analyzing diverse problems and situations, enabling predictions, decision-making, and practical applications in daily life. Program for International Student Assessment (PISA), initiated by the Organization for Economic Co-operation and Development, is designed to gauge the efficacy of education systems in preparing young individuals for essential skills required to thrive in a dynamic world. PISA conducts assessments on 15-year-olds, considered to have completed compulsory education, every three years. In the 2022 PISA mathematics examination for Thai students (IPST, 2023), it was noted that Thai students achieved an average score of 394 in mathematics, 409 in science, and 379 in reading. As compared to the 2018 PISA results, there has been a decline in the average scores for all

three subjects among Thai students, with a notable decrease of 25 points in the average math score. It is essential to recognize that the fundamental assessment framework of PISA revolves around evaluating reasoning and problem-solving abilities.

Through the teaching of integer and percentage word problems, the researcher observed that students often struggled to analyze and interpret the problems, finding it difficult to visualize the situations presented. This observation is consistent with the findings of Kusuma and Retnawati (2019), who analyzed sixth graders' difficulties in solving word problems involving whole numbers, fractions, and decimals. Their study revealed that these difficulties arose from several factors, including challenges in comprehending the problem context, misconceptions in understanding fractional operations, limited numeracy skills, and procedural inaccuracies.

Building on this line of evidence, Thipkong and Davis (1991) examined preservice teachers' misconceptions in interpreting and applying decimals in mathematical problem-solving, such as

multiplication and division of decimals. Despite their formal mathematical training, many of these prospective teachers still exhibited persistent misconceptions, indicating that misunderstandings of decimal concepts can extend even to higher levels of education. Further research reinforces these concerns. Resnick et al. (1989) found that elementary students frequently adhered to flawed strategies, such as assuming that decimals with more digits are always larger—for instance, believing that $0.125 > 0.300$ simply because it appears longer. They categorized such systematic errors under heuristics like the “longer-is-larger” and “shorter-is-larger” rules. Similarly, Moloney and Stacey (1997) reported that, although students were often able to perform calculations, they continued to rely on faulty reasoning when comparing decimals, including misinterpreting place value and misunderstanding the role of zeros in decimal places. Taken together, these studies demonstrate that misconceptions about decimals are not only common but also deeply ingrained, often preventing learners from translating contextual problems into accurate mathematical expressions. This highlights a critical research gap: while prior studies have identified the prevalence and persistence of decimal misconceptions, fewer have explored how innovative instructional approaches—particularly visualization-based strategies—can directly address these challenges. Recognizing this, the present study emphasizes the need to adopt teaching methods that enhance visualization, strengthen conceptual understanding, and foster efficient problem-solving skills. In particular, the bar model technique holds strong potential to support students in overcoming persistent misconceptions and improving their ability to solve decimal word problems.

A wide range of instructional innovations has been developed to support students in mathematical problem-solving, among which the bar model technique has emerged as one of the most effective strategies (MCC@WCCUSD, 2019; Third Space Learning, n.d.). The bar model, a visualization method that represents numerical relationships through rectangular bars, allows learners to break down complex word problems into simpler, more manageable components. This strategy not only facilitates the translation of real-world contexts into mathematical expressions but also strengthens students’ logical reasoning and systematic problem-solving processes. The effectiveness of the bar model has been widely documented. Research demonstrates its success in enhancing students’ proficiency in solving word problems (Abdul Gani et al., 2019; Maputol, 2019; Osman et al., 2018; Shah, 2022; Shah et al., 2021) and in promoting a deeper understanding of mathematical concepts (Jahudin & Siew, 2023; Lestiana & Wanita, 2019; Matzin & Mundia, 2017; Thirunavukkarasu & Senthilnathan, 2017). Beyond cognitive development, the bar model has also been applied to improve learning behaviors and metacognitive strategies within structured frameworks (Abbas et al., n.d.; Hough et al., n.d.; Karim & Puteh, 2021; Khairiree, n.d.; Malai & Prasertsang, 2023; Ramasamy & Puteh, 2018).

In the Thai context, numerous studies have applied the bar model to strengthen problem-solving abilities and improve students’ overall achievement in mathematics (Chaisongkram, 2019; Juijit et al., 2022; Ketprakob et al., 2021; Pativisan, 2024; Ratta, 2013; Sengaium, 2012; Sremahaprom, 2006; Srinonyang & Seehamongkon, 2023). However, despite these advances, decimal word problems remain a persistent challenge for many students. Misconceptions related to place value, alignment of decimal points, and interpretation of decimal quantities often hinder accurate problem-solving. Recognizing these difficulties,

the bar model has been identified as a promising pedagogical tool to address such misconceptions. By providing a clear visual structure, it enables students to conceptualize decimal relationships more effectively, reduces computational errors, and fosters confidence in approaching complex word problems. This study therefore seeks to extend the application of the bar model specifically to decimal problem-solving, aiming to explore its potential in improving both efficiency and conceptual understanding in mathematics learning.

METHODS

This study employed a mixed-method research design, integrating both quantitative and qualitative approaches, with a one-group pre-/post-test model. The class consisted of 29 sixth-grade students; however, the study specifically focused on learners who demonstrated difficulties in solving decimal word problems. To identify these students, a diagnostic test was administered. Those who scored below 65% of the total score were classified as having significant learning difficulties. Based on this criterion, 15 students were identified as requiring targeted support. From this group, six students were randomly selected for in-depth interviews to obtain qualitative insights into their misconceptions and problem-solving processes.

Research Instruments

Learning management plans using the bar model for decimal problem-solving

Six lesson plans were designed, covering a total of six instructional hours across a two-week period. Each plan emphasized the systematic use of the bar model as a visualization strategy for representing decimal relationships and solving contextual word problems. The plans were reviewed for content validity and pedagogical appropriateness by three experts: one specialist in mathematics education and two experienced school mathematics teachers.

Mathematics achievement test on decimal problem-solving

A test consisting of five open-ended problems was constructed to measure students’ ability to analyze, represent, and solve decimal word problems using the bar model. The test items were evaluated by three experts for validity and alignment with the learning objectives. A pilot administration with 10 students was conducted to refine item clarity and ensure appropriate levels of difficulty.

Bar model decimal problem-solving exercises

A set of structured practice exercises was developed to reinforce students’ proficiency in applying the bar model. These exercises aimed to provide step-by-step scaffolding, allowing students to visualize decimal operations, check their reasoning, and build confidence in solving increasingly complex problems.

Interview protocols

Semi-structured interview forms were designed to investigate students’ problem-solving processes, misconceptions, and perceptions of the bar model technique. Interviews were conducted with the six selected students both before and after the intervention, allowing for comparative analysis of changes in their understanding and strategies.

Data Collection

The researcher developed a set of decimal problem-solving exercises based on the bar model method (Thiengtrong, 2020), with the

quality of the materials ensured through expert validation by specialists in mathematics education. The study was conducted with sixth-grade students at Surat Thani School, Surat Thani Province. A total of fifteen students, identified as having difficulties in solving decimal problems, were selected for participation using a one-group pre-/post-test design. Data were collected through both quantitative and qualitative methods, as outlined below:

Pre-test

Prior to the intervention, a pre-test consisting of five open-ended questions was administered. This assessment provided baseline data on students' proficiency in solving decimal word problems before the introduction of the bar model technique.

Instructional sessions

Students received explicit instruction on the principles and applications of the bar model for solving decimal problems. The sessions emphasized visualization, step-by-step representation, and systematic reasoning as central components of the strategy.

Implementation of exercises

Following instruction, students completed five structured practice exercises designed to reinforce the use of the bar model in solving decimal problems. Performance data were collected during this phase to monitor progress and identify persistent misconceptions.

Post-test

At the conclusion of the intervention, a post-test consisting of five open-ended problems, parallel in structure and difficulty to the pre-test, was administered. The results were used to evaluate the effectiveness of the bar model approach in enhancing students' achievement in decimal problem-solving.

Interviews

To gain qualitative insights, six students from the target group were randomly selected for semi-structured interviews. The interviews explored students' thought processes, difficulties encountered, and perceptions of how the bar model supported their understanding of decimal operations.

RESULTS

Presenting the results of the data analysis in the study on the impact of using the bar model on the learning efficiency of decimal problem-solving for the sixth-grade students at Suratthani School, the researcher provides the following:

Quantitative Data Analysis

Section 1: Comparative Analysis of Learning Efficiency from Learning Management Using Decimal Problem-Solving Practice with the Bar Model for the sixth-grade students

In this section, we present the results of a comparative analysis of learning efficiency scores before and after the implementation of learning management through decimal problem-solving practice using the Bar Model. The outcomes of this analysis are depicted in **Table 1**.

Table 1. Results of the comparative analysis of learning efficiency among sixth grade students

Score	N	\bar{X}	S.D.	df	t
Pre-test	15	11.20	1.37	14	15.23
Post-test		16.73	2.02	14	

* Significant statistical findings at the 0.05 significance level

From **Table 1**, it is evident that the learning efficiency of students after the intervention is significantly higher than before, at a statistically significant level of 0.05. The average learning efficiency of students after the implementation of the learning management approach, utilizing decimal problem-solving practice with the Bar Model is 16.73 with a standard deviation of 2.02. In contrast, the average learning efficiency of students before the intervention is 11.20 with a standard deviation of 1.37. The discrepancy between the posttest and pretest scores was 5.53. The developmental scores of each student are presented in **Figure 1**.



Figure 1. Developmental scores of students (Figure created by the authors based on the data from the present study)

From **Figure 1**, it is evident that the post-test scores differ significantly from the pre-test scores for all students.

Section 2 focuses on the analysis of the effectiveness of the bar model on learning efficiency in decimal problem-solving, meeting the criteria (70/70). The results from the field experiment involving 15 participants are presented in **Table 2** and **Table 3**.

Table 2. Assessment of the effectiveness of the bar model on learning efficiency in decimal problem-solving based on the criteria (70/70)

Student	Score between learning (30)	The post-test score(20)
1	21	15
2	20	15
3	24	16
4	27	17
5	24	18
6	20	15
7	23	16
8	21	14
9	19	14
10	27	19
11	30	20
12	21	16
13	25	18
14	27	18
15	30	20
Sum	359	251
Mean score	23.93	16.73
Standard deviation	3.63	2.02
Effectiveness	$E_1 > 79.77$	$E_2 > 83.65$

Table 3. Results of assessing the effectiveness of the bar model in decimal problem-solving for the sixth grade school students from the field experiment involving 15 participants

Efficiency	Max	M	Standard deviation	Percentage (%)
Efficiency of the process	30	23.93	3.63	79.77
Efficiency of the outcomes	20	16.73	2.02	83.65

Note. The effectiveness of the bar model in decimal problem-solving is equivalent to 79.77/83.65

From **Table 2** and **Table 3**, it is evident that the average scores from the decimal problem-solving practice using the bar model, conducted in the field experiment with 15 participants, have a mean of 23.93 points. The post-test scores measuring learning efficiency after the intervention have an average of 16.73 points, equivalent to a percentage average of 79.77% and 83.65%, respectively. This indicates that the efficacy of the decimal problem-solving practice with the bar model for the sixth-grade students is 79.77/83.65, surpassing the predetermined benchmark.

Qualitative Data Analysis

The analysis of qualitative data is derived from two segments: the responses in the pre- and post-test, and from interviews conducted with students in the target group. Conducted interviews with the 6 students, randomly selected from a sample group of 15 students. The interviews took place after the pre-test, before practicing decimal problem-solving with the bar model, and after completing the post-test. During the

interviews, two students revealed that in the pre-test, they could answer only two questions correctly, while the remaining three were incorrect or guesses. However, after learning the bar model, they successfully answered all the questions. The post-learning interviews indicated that the bar model significantly improved their ability to solve problems quickly and accurately. With clear developmental progress evident, as illustrated in **Figure 2**, there are examples of students who have shown significant improvement.

From **Figure 2**, it is evident that students utilize the bar model to analyze the information provided in the problem and address the questions posed, leading to the derivation of solutions.

During the interview with student number 6, it was revealed that before the lesson, the student could only answer 1 question correctly, and for the remaining 4 questions, there were miscalculations, misinterpretation of the problem, and guesses. However, after studying the bar model, the student managed to correctly answer 4 questions. The post-lesson interview indicates that the bar model helps students find answers more quickly with fewer errors. Students exhibit improved thinking clarity, as illustrated in **Figure 3**.

From **Figure 3**, it is evident that even students showed significant improvement after learning with the bar model. Students demonstrated effective learning and accurate problem-solving skills using the bar model.

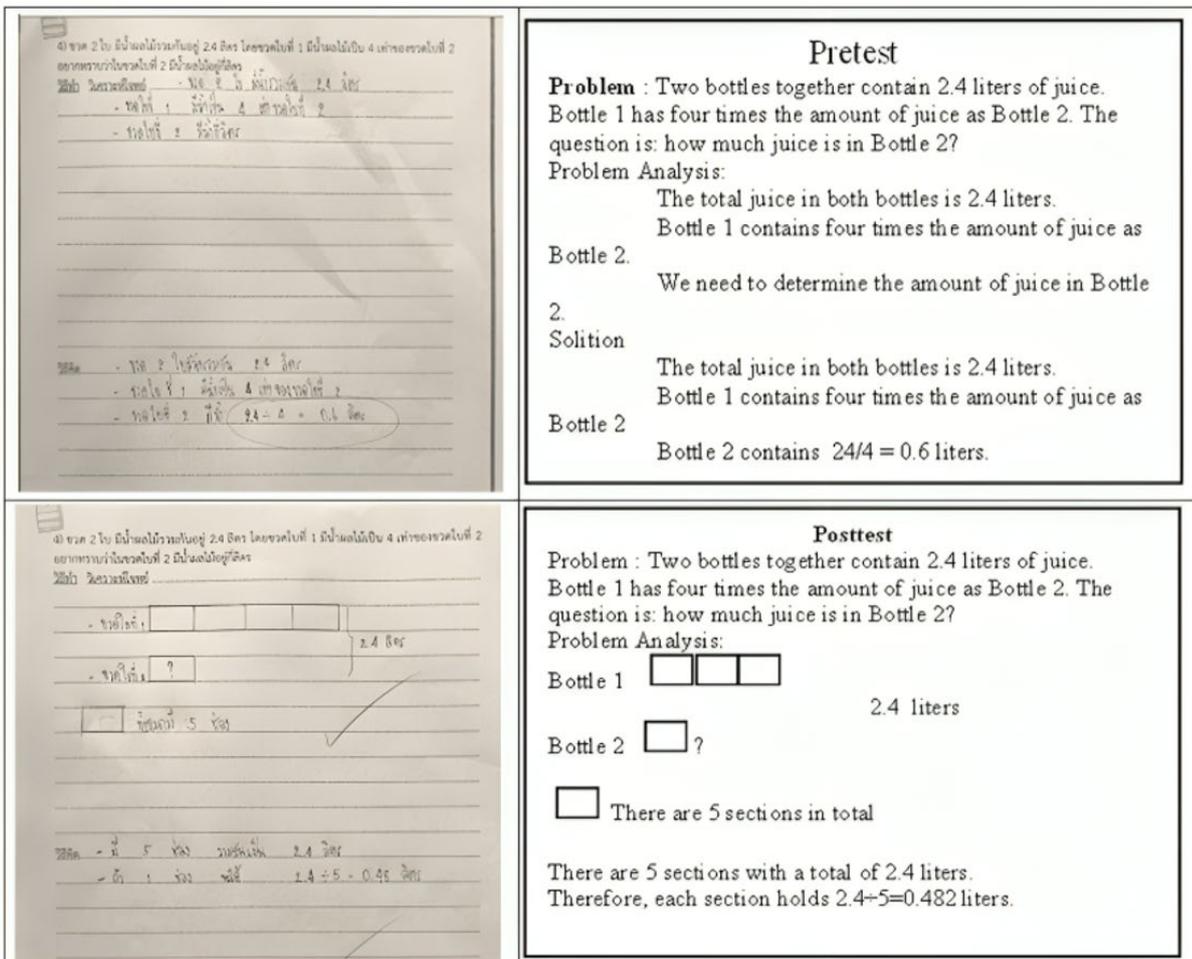


Figure 2. Example of a student showing significant improvement (Figure created by the authors based on the data from the present study)

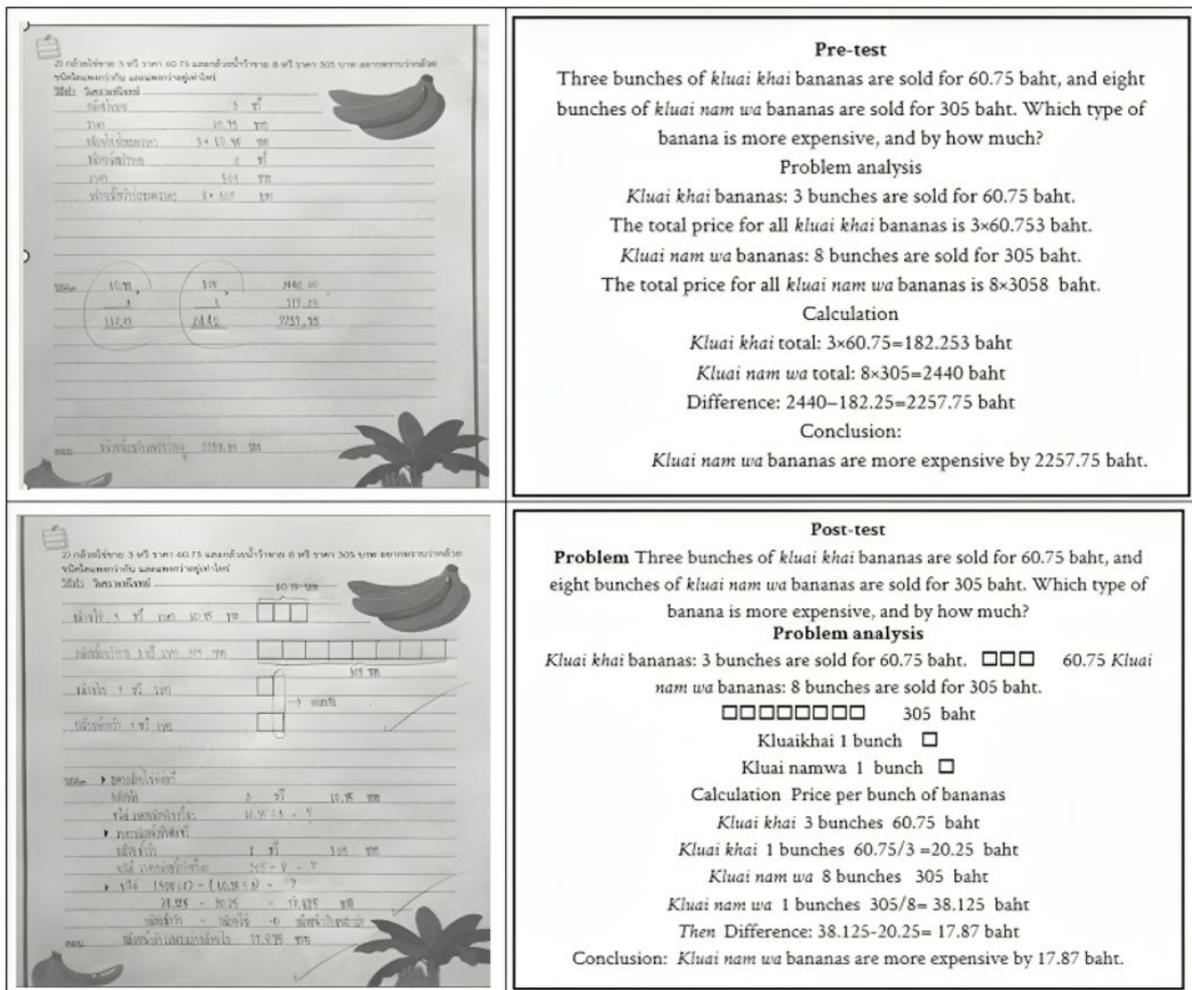


Figure 3. Example of Student 2's improved response (Figure created by the authors based on the data from the present study)

Table 4. Score improvement of the target group

Student in target group	Number of correct answers before instruction (5 question)	Percentage (%)	Number of correct answers after instruction (5 questions)	Percentage (%)
1	3	60	5	100
2	3	60	5	100
3	2	40	5	100
4	2	40	4	80
5	2	40	4	80
6	1	20	4	80
Average		43.33		90

From the interviews it was observed that all six students showed an improvement in scores. The score improvement ranged from 40% to 60%, as indicated in Table 4.

The interviews showed that students have improved in interpreting the meaning of each decimal problem, analyzing the decimal problems by drawing bar models, enabling them to express them in symbolic sentences and find solutions more effectively.

DISCUSSION

The findings of this study indicate that the use of the bar model technique had a significant positive effect on students' achievement in solving decimal word problems. The discussion of the results in relation to the study's objectives is presented as follows.

Improvement in Learning Achievement

The post-instruction achievement scores of the students improved significantly compared to their pre-instruction results, with the average increasing from 11.20 to 16.73, which was statistically significant at the .05 level. This improvement can be attributed to the effectiveness of the bar model as a visualization strategy that transforms abstract decimal concepts into more concrete representations.

By enabling students to illustrate quantities and relationships, the bar model reduces misconceptions, promotes logical reasoning, and helps learners systematically translate contextual problems into mathematical expressions. These findings are consistent with Morin et al. (2017), who found that bar model drawings assist students with mathematical difficulties by making problem contexts more comprehensible, as well as with Knuth et al. (2011), who demonstrated

that visual models support middle school students in understanding algebraic equivalence and variables. The structured progression of this study—from simple to complex decimal problems—also reflects recommendations from Chaisongkram (2019), Matzin and Mundia (2020), and Lestiana and Wanita (2019), who highlight that scaffolding and visualization techniques help sustain students' engagement while addressing persistent difficulties in mathematics learning.

Efficiency of the Bar Model Exercises

The instructional efficiency achieved through the bar model intervention was 79.77/83.65, surpassing the minimum standard of 70/70. This indicates that students not only achieved higher levels of accuracy but also demonstrated sustained learning effectiveness throughout the intervention. The success of these exercises can be attributed to their systematic design, which was grounded in curriculum objectives, principles of problem-solving pedagogy, and expert validation. The incorporation of visual representation in every step of the problem-solving process ensured that students could gradually internalize strategies, monitor their reasoning, and apply decimal operations more confidently. This result is in line with research by Intasung (2002), Khairiree (n.d.), and Madani et al. (2018), which emphasized that carefully designed instructional tools improve both conceptual understanding and learner motivation. Similarly, Ramasamy and Puteh (2018) and Karim and Puteh (2021) confirmed that visualization-based methods, when systematically developed and validated, lead to effective and efficient learning outcomes.

Overall Implications

Taken together, the results of this study reaffirm that the bar model is not merely a computational aid but a strategic visualization tool that directly addresses students' misconceptions about decimals, such as misinterpreting place value, misaligning decimal points, or misjudging magnitudes based on digit length. By bridging the gap between textual information in word problems and symbolic mathematical representation, the bar model fosters both efficiency and significance in mathematics learning. This suggests that integrating bar model techniques into regular mathematics instruction could enhance students' confidence, accuracy, and long-term problem-solving proficiency, especially in the area of decimal word problems where misconceptions are deeply ingrained.

CONCLUSION

The findings of this study confirm that the bar model technique is a highly effective instructional strategy for improving students' achievement in decimal problem-solving. First, students' post-instruction scores increased significantly compared to their pre-instruction results, with statistical analysis at the .05 level confirming that the intervention had a meaningful impact. This indicates that the bar model, by supporting visualization and systematic reasoning, helps students overcome persistent misconceptions related to place value, decimal alignment, and contextual interpretation of word problems. Second, the instructional efficiency achieved—79.77/83.65, which exceeded the 70/70 benchmark—demonstrates that the bar model not only enhances achievement but also promotes efficient learning processes. This highlights the dual benefit of the bar model as both a conceptual visualization tool and a pedagogical innovation that strengthens students' ability to translate real-life contexts into accurate

mathematical expressions. Taken together, these results underscore the significance of integrating visualization-based strategies such as the bar model into mathematics instruction, particularly for complex and error-prone topics like decimals. By addressing conceptual misunderstandings and providing a clear structure for reasoning, the bar model enables students to build confidence, accuracy, and transferable problem-solving skills.

Recommendations for Future Research

1. Investigate and compare alternative instructional approaches with the bar model to determine relative effectiveness.
2. Apply the bar model technique to other mathematical content areas, such as fractions, ratios, or algebraic word problems.
3. Extend the research to different educational levels (primary or upper secondary) to examine its adaptability across age groups.
4. Explore the effects of the bar model on learners with diverse learning styles or examine its adaptability in different cultural and classroom contexts.

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KS: investigation, data curation, writing – review & editing. Both authors approved the final version of the article.

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Ethics declaration: This study was conducted in strict accordance with the principles of human research ethics. The research posed no more than minimal risk to participants, meaning that the level of risk did not exceed that encountered in normal daily life activities. Data collection took place in a classroom setting through the administration of pre-test and post-test instruments. Permission was obtained from the school administration, and informed consent was obtained from all participating students. All data were anonymized and used solely for research purposes to protect the privacy and confidentiality of the participants. Furthermore, Assistant Professor Dr. Bunyisa Saelo has successfully completed certified training in human research ethics prior to conducting this study.

AI statement: In this study, artificial intelligence (AI: Chat GPT) tools were employed to assist in translating content from Thai to English. Minor adjustments were subsequently made to refine the wording and ensure appropriateness in the research context, and all content was verified for scientific accuracy and compliance with academic standards.

Declaration of interest: Authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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