

The role of visual representation in primary student's ability to solve fraction word problems

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Abstrak Kesulitan dalam menyelesaikan soal cerita pecahan masih menjadi tantangan yang persisten dalam pendidikan matematika tingkat dasar, karena siswa mengalami kesulitan dalam menerjemahkan situasi soal tertulis menjadi representasi matematis yang tepat dan operasi yang sesuai atau sebaliknya. Penelitian ini mengkaji dampak representasi visual terhadap kemampuan siswa sekolah dasar dalam menyelesaikan soal cerita pecahan. Meskipun pecahan merupakan konsep dasar dalam perkembangan matematika, siswa sering kesulitan dalam menerjemahkan soal tertulis menjadi operasi matematika. Melalui tinjauan literatur sistematis berdasarkan kerangka kerja PRISMA, 28 artikel yang diterbitkan antara tahun 2015 dan 2025 dari database Semantic Scholar, ERIC, dan Scopus menggunakan alat SPIDER untuk pemilihan kata kunci. Temuan menunjukkan bahwa model area paling sering digunakan, diikuti oleh garis bilangan, model batang, dan model himpunan; selain itu, temuan tersebut juga mengindikasikan bahwa representasi visual berkaitan dengan peningkatan kemampuan dalam memecahkan soal cerita pecahan dan dapat mendukung pemahaman konseptual siswa tentang pecahan dengan cara mengorganisasikan informasi serta memberikan ilustrasi konkret atas konsep-konsep abstrak.

Kata kunci *Representasi visual, Representasi matematis, Soal cerita, Pecahan, Sekolah dasar*

Abstract Difficulties in solving fraction word problems remain a persistent challenge in elementary mathematics education, as students struggle to translate written situations into appropriate mathematical representations and corresponding operations, or vice versa. This study explores how visual representation contributes to primary students' ability to solve fraction word problems. Despite fractions being fundamental for mathematics advancement, students struggle with translating written problems into mathematical operations. Through a systematic literature review following the PRISMA framework, 28 peer-reviewed articles that were published between 2015 and 2025 were analyzed from Semantic Scholar, ERIC, and Scopus databases using the SPIDER tools for keyword selection. The findings reveal that area models were most frequently used, followed by number lines, bar models, and set models. Furthermore, the findings suggest that visual representations are associated with improved performance in solving fraction word problems and may support students' conceptual understanding of fractions by organizing information and providing concrete illustrations of abstract concepts.

Keywords *Visual representation, Mathematical representation, Word-problem, Fraction, Elementary school*

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Introduction

Fractions are a fundamental yet challenging concept for primary students, as they require a nuanced understanding of part-whole relationships and proportional reasoning. Research highlights that even students who excel in whole-number arithmetic often struggle with fractions, particularly in word problems that require interpreting real-world scenarios (Prayitno et al., 2021). These struggles are not trivial, as fractions form the base for advanced mathematics, including algebra, ratios, and percentages. Without solid fundamental skills in base concepts, students risk falling behind in later grades.

One of the main obstacles in fraction word questions is that, unlike straightforward equations, these problems require students to translate written descriptions into mathematical operations and to connect their mathematical knowledge to real-life situations (Aurelia et al., 2024; Krawitz et al., 2018). Unlike symbolic exercises, word problems demand that students identify the relevant quantities, determine the underlying relationships, and connect mathematical operations to contextual meaning. For example, a question that asks, “If a pizza is divided equally among three friends, how much does each get?” seems simple but involves understanding division as sharing, visualizing the pizza as a whole, and recognizing that $\frac{1}{3}$ represents one part of three equal parts. Errors in this process, such as misidentifying the whole or incorrectly applying operations, are common and often caused by conceptual understanding gaps (Prayitno et al., 2021). These errors highlight the need for teaching strategies that make abstract fractional concepts real.

Visual representations have emerged as a promising tool to address these challenges and enhance students’ ability to solve fraction word problems. As Jitendra et al. (2016) highlight, embedding visual models such as schema diagrams in instructional approaches significantly enhances students’ abilities to solve mathematical word problems. Studies have shown that visual aids, such as diagrams and models, can significantly improve students’ comprehension of mathematical concepts and problem-solving skills (Prayitno et al., 2021). Tools such as diagrams, bar models, and digital manipulatives act as a bridge, transforming abstract ideas into something students can see and interact with. These visual tools help students bridge the gap between abstract mathematical concepts and tangible understanding, ultimately improving problem-solving skills and performance in mathematics (Flores et al., 2019; Jitendra et al., 2016). Visual representations help students develop a deeper understanding of fractions by providing a concrete and tangible way to explore abstract mathematical ideas (Chang et al., 2024). Studies show that when students draw or manipulate visuals, they engage more deeply with the problem, which leads to better understanding and fewer mistakes (Gonzalez Aguilar et al., 2019).

One key explanation for the effectiveness of visual representations lies in their ability to reduce cognitive load. Fraction word problems often place heavy demands on working memory, requiring students to simultaneously process linguistic information, numerical relationships, and operational decisions. Visual representations lighten this burden by organizing information spatially and making relationships explicit (Purcar et al., 2024). According to studies by Ruliani et al. (2018), students who utilize visual representations often demonstrate greater problem-solving abilities because these tools help organize and clarify their thought processes. Fraction problems often overload working memory because they require many steps: reading the question, identifying the relevant numbers, choosing the operation, and performing the calculation. Visuals simplify this process by externalizing information. A bar model, for

example, can help students break a problem into segments, making relationships between quantities clearer (Osman et al., 2018). This visual scaffolding allows students to focus on problem-solving rather than being overwhelmed by abstract numbers.

In line with Widodo et al.'s (2018) statement that visualization can enhance students' ability to grasp complex mathematical concepts and solve problems efficiently. For instance, Barbosa and Vale (2021) emphasize that visual thinking is integral to developing mathematical solutions, as it simplifies and clarifies the problem-solving process. The use of visual aids supports the concrete-representational-abstract (CRA) instructional sequence, which has been shown to effectively scaffold students' understanding of fraction concepts (Flores et al., 2019). This approach helps students transition from concrete manipulatives to more abstract representations while solidifying their understanding of fractional relationships. Research indicates that students who engage with visual aids benefit in the short term and develop lasting conceptual understandings that support future mathematical learning (Dewolf et al., 2014).

However, not all visual representations are equally effective. The effectiveness of visual representations can vary based on the type of visual aid used and the instructional context. Different representations may target specific fractional concepts, requiring educators to carefully select visuals that align with students' developmental stages (Cady et al., 2015; Deringöl, 2019). Although previous reviews have examined visual representations in mathematics or problem-solving in general (Nugroho et al., 2020; Utama & Prabawanto, 2021), there remains a lack of synthesized evidence specifically addressing how visual representations support primary students in solving fraction word problems. Existing studies have focused on the unique challenges of teaching fractions to elementary school students. One significant limitation is the absence of synthesized reviews addressing visual strategies tailored to fraction word problems. Existing syntheses often ignore how developmental factors, such as a child's limited attention span or concrete operational thinking, shape the effectiveness of visual aids. Elementary school students benefit from physical fraction blocks rather than abstract number lines. To address this gap, the present study systematically reviews and synthesizes empirical research on the use of visual representations in supporting primary students' fraction word problem solving, with the aim of identifying dominant trends, instructional implications, and underexplored representational approaches that can inform more effective fraction instruction in primary mathematics education. Specifically, it seeks to answer the following research questions:

RQ1. How do visual representations impact primary students' ability to solve fraction word-problems?

RQ2. How do visual representations reduce cognitive load and enhance students' conceptual understanding of fractions?

Methods

Design

This study adopts a systematic literature review (SLR) methodology, guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, to synthesize peer-reviewed research on visual representations in fraction problem-solving. The SLR protocol ensures methodological rigor through transparent search strategies, inclusion criteria, and thematic analysis. The identification process for relevant literature was conducted in February 2025. A comprehensive search was conducted across three electronic databases:

Semantic Scholar, ERIC, and Scopus. Keywords were selected to capture the focus on *visual representations* and *fraction problem-solving* in *primary education mathematics* using the SPIDER tools and Boolean operators (AND/OR) to combine specific keywords, as shown in Table 1.

Table 1. The SPIDER tools for specific keywords

The SPIDER	Keywords
S (Sample)	"primary school" OR "elementary school" OR "K-6" OR "child" OR "student" AND
P and I (Phenomenon of Interest)	"visual representation" OR "visual aid" OR "visual model" OR "diagram" OR "bar model" OR "fraction circle" OR "number line" OR "area model" OR "digital manipulatives" AND
D (Design)	"word problem" OR "problem-solving" OR "mathematical problem" OR "fraction word problem" AND
E (Evaluation)	"mathematical ability" OR "problem solving accuracy" OR "conceptual understanding" OR "mathematics learning" AND
R (Research Type)	"experiment" OR "analysis" OR "qualitative" OR "mixed-methods"

The literature search was conducted in March 2025 using three electronic databases: Scopus, ERIC, and Semantic Scholar (via Publish or Perish). However, because the ERIC database is not included in the *Publish or Perish* search database, the ERIC database search is done manually by entering the search string in the search column on the database website. The search strategy was developed using the SPIDER tool, as detailed in Table 1. Due to differences in search engine capabilities and syntax requirements across databases, the search strings were adapted for each database while maintaining the core concepts. The complete search strings used for each database are provided below. Filters were applied to limit results to peer-reviewed articles and conference papers published in English or Indonesian between 2015 and 2025, ensuring that the research is directly relevant to contemporary educational practices.

Scopus Search String*:

(TITLE-ABS-KEY ("visual representation" OR "visual aid" OR "bar model" OR "number line" OR "area model") AND TITLE-ABS-KEY ("fraction" OR "proportional reasoning") AND TITLE-ABS-KEY ("primary school" OR "elementary school") AND TITLE-ABS-KEY ("word problem" OR "problem-solving") AND TITLE-ABS-KEY ("mathematics education")) AND PUBYEAR > 2015 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Indonesian"))

ERIC Search String*:

(("visual representation" OR "visual aid" OR "diagram" OR "bar model" OR "number line") AND ("fraction" OR "proportional reasoning") AND ("primary school" OR "elementary school" OR "K-6") AND ("word problem" OR "problem-solving")) AND (PY 2015-2025)

Semantic Scholar (Publish or Perish) Search String*:

((visual* OR represent* OR diagram* OR model*) AND (fraction* OR "word problem*") AND (primary OR elementary) AND (math* OR arithmetic*)) AND PUBYEAR > 2015 AND PUBYEAR < 2025

*Given the exploratory nature of the search and the limitations of the Publish or Perish software for complex Boolean queries in Semantic Scholar, multiple search iterations were performed with simplified strings. The final set of 479 records represents the combined results from all search variations after duplicate removal. This approach, while less standardized than a single-string search, is considered acceptable in systematic reviews to maximize sensitivity when database syntax varies (Lagisz et al., 2025).

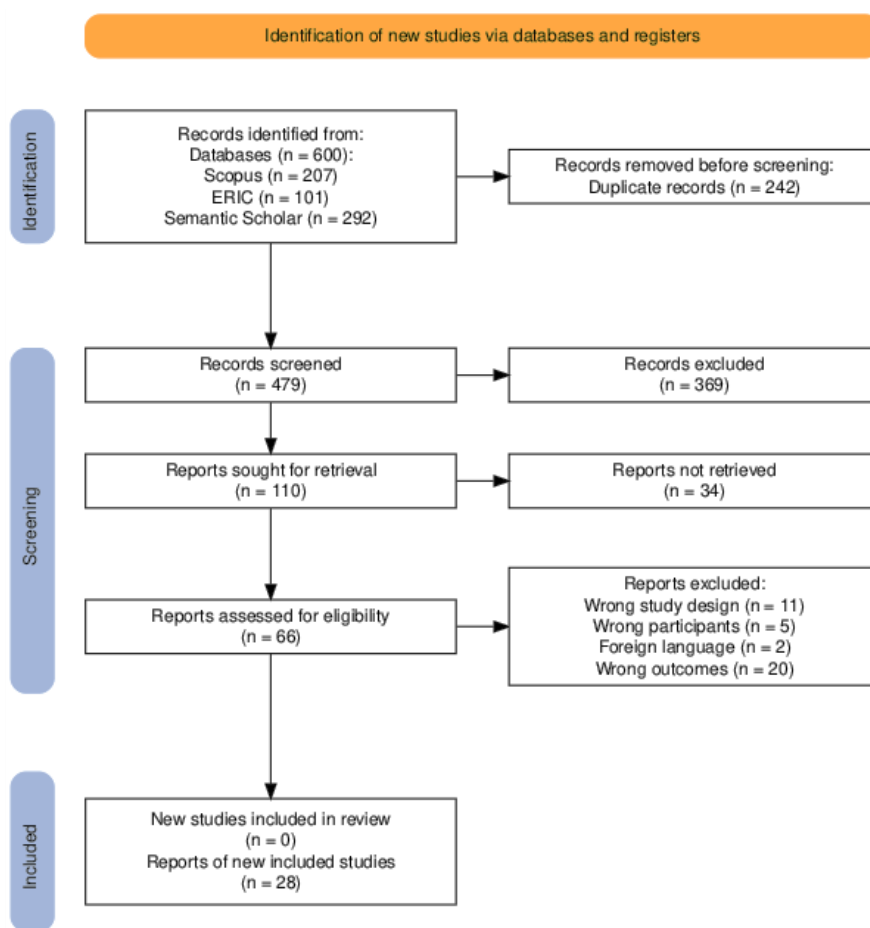


Figure 1. Flowchart of PRISMA framework

The initial search across the three databases (Scopus, ERIC, and Semantic Scholar) yielded a total of 479 records. These records were exported to a reference manager, and 305 duplicate records were removed. The remaining 174 records were screened based on their titles and abstracts. During this screening phase, 108 records were excluded as they did not meet the basic inclusion criteria (e.g., wrong population, not focused on fractions, or not original research). Consequently, 66 full-text articles were sought for retrieval and assessed for eligibility. A full-text review was conducted on these 66 articles, resulting in the exclusion of 38 articles for the

following reasons: the study designs were not practically research articles (n=12); the study participants were not primary school students (n=5); the intervention did not focus on visual representations and did not address word problems specifically (n=20); and the language was other than Indonesian and English (n=2). The final number of studies included in this systematic review is 28. The flowchart in [Figure 1](#) outlines the three-step PRISMA protocol: identification, screening, and inclusion.

For the current review, we focused on primary research that presents original data from primary sources. We reviewed the abstracts of 174 identified studies to exclude articles that were not primary research or did not include a mathematics outcome. We examined a total of studies that further met these criteria to determine whether each study would be included in the present review using the following eligibility criteria, which are listed in [Table 2](#).

Table 2. Eligibility criteria for SLR protocol

Criteria	Inclusion	Exclusion
Time period	2015-2025	Studies published before 2015
Language	English, Indonesia	Other than Indonesian and English
Type of article	Original research article in peer reviewed journal and conference papers	Systematic reviews/meta-analysis, unpublished research.
Study focus	Studies explicitly addressing visual representations in fraction word problems	Nil
Exposure of interest	Use of visual representations (e.g., diagrams, bar models, number lines)	Studies not focused on visual representations
Participants	Primary school students (ages 7–12)	Any participants outside primary school-age-students
Study design	Experimental, qualitative, or mixed-methods designs	Non-primary studies, theoretical papers

Prior to data extraction, all included studies underwent a quality appraisal using a structured checklist adapted from established SLR guidelines for educational research. Only studies meeting minimum quality standards were retained for synthesis.

Data extraction and analysis

The initial screening of the literature identified 479 articles. These were then deduplicated and assessed for eligibility through a review of titles and abstracts. A full-text analysis was conducted on 66 articles that appeared to meet our criteria at first glance. Ultimately, 28 papers satisfied the final inclusion criteria. Data extraction from these selected studies concentrated on several key aspects:

1. The study focused on primary school children of any grade.
2. It included various types of visual representations used in solving fraction problems.
3. It featured an intervention involving these representations. We define 'representations' as diagrams, sketches, pictures, or other visualizations that symbolize abstract mathematical concepts related to fractions.

4. The study evaluated outcomes regarding the impact of representation on problem-solving abilities, students' understanding of fractions, and the reduction of cognitive load.
5. The study utilized experimental, qualitative, and other methodologies that provided sufficient information about the benefits of visual representations on students' ability to solve real-world fraction problems.

Following data extraction, a qualitative content analysis was conducted to synthesize findings across studies. The extracted data was systematically coded and categorized based on (a) types of visual representations (e.g., area models, set models, bar models), (b) instructional purposes (e.g., conceptual development, procedural support, problem interpretation), and (c) reported learning outcomes. Patterns and recurring themes were identified by comparing results across studies, with particular attention to consistencies and divergences in how different representations influenced students' fraction understanding and problem-solving processes. This analytical process enabled the identification of dominant research trends, underrepresented representation types, and gaps in existing literature.

To assess the methodological quality of the included studies, a quality appraisal was conducted prior to data synthesis. An adapted checklist was developed based on established guidelines for systematic reviews in educational research. The checklist evaluated studies on key criteria such as clarity of research objectives, appropriateness of study design for addressing the research questions, rigor of data collection and analysis, and justification of conclusions. Each study was independently assessed by two reviewers and given a rating of "High," "Moderate," or "Low" quality based on the number of criteria met. Studies that did not meet the minimum quality threshold were discussed among the reviewers; however, no studies were excluded based on quality to ensure a comprehensive synthesis of the available literature. The results of the quality appraisal are summarized in [Table 3](#). This appraisal was considered when formulating the conclusions, leading to more cautious and nuanced interpretations of the overall findings.

Table 3. Study quality appraisal


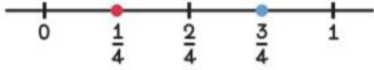

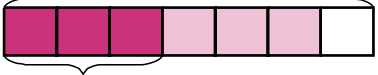
Study	Study design	Quality rating
Agusfianuddin et al. (2024)	Qualitative	High
Arianto & Supardi (2024)	Experimental	High
Ayabe et al. (2021)	Qualitative	Moderate
Barbosa & Vale (2021)	Qualitative	High
Chan & Kwan (2021)	Experimental	Moderate
Chususiyah et al. (2021)	Qualitative	High
Çimen & Kartal (2021)	Qualitative	Moderate
Colonnese et al. (2026)	Qualitative	High
Cramer et al. (2019)	Experimental	High
Flores (2019)	Qualitative	Moderate
Fuchs et al. (2020)	Qualitative	Moderate
Fukuda et al. (2021)	Experimental	Low
Ha (2025)	Experimental	Moderate
Fang et al. (2023)	Qualitative	High
Hidayatullah et al. (2024)	Qualitative	Moderate
Hwang et al. (2023)	Experimental	Moderate

Study	Study design	Quality rating
Imaniyah & Fiantika (2024)	Experimental	Moderate
Jiang (2021)	Qualitative	High
Kamid et al. (2023)	Qualitative	Low
Mahama & Kyeremeh (2023)	Experimental	Moderate
Pearn et al. (2018)	Qualitative	High
Shah (2022)	Experimental	High
Suryaningrum et al. (2020)	Qualitative	Moderate
Valenzuela-Ochoa et al. (2023)	Experimental	High
Widjaja et al. (2025)	R&D	High
Khoo et al. (2025)	Mixed-method	Low
Jitendra & Woodward (2019)	Qualitative	High
Unaenah et al. (2024)	Qualitative	Low

Findings

This study examined twenty-eight relevant papers published between 2015 and 2025. The analysis of these papers revealed that various types of visual representations were utilized to enhance students' understanding of fraction problems. The different types of visual representations are detailed in Table 4, and their usage distribution is illustrated in Figure 2.

Table 4. Types of visual representation in fraction word-problems

Type	Description	Example
Area model	Uses geometric shapes to partition an area to represent fractions visually.	
Number lines	Represent fractions as points on a number line, highlighting equivalency and operations.	
Set model	Uses groups of objects to show fractions, emphasizing part-to-whole relationships in discrete quantities.	
Bar model (tape diagram)	Uses proportional rectangular bars to compare fraction values visually.	

Type	Number of studies using
Area model	23 studies
Number lines	4 studies
Bar model (Tape diagram)	3 studies
Set model	1 study

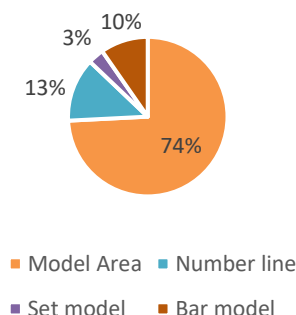


Figure 2. Distribution of visual representation types used in fraction problem

Based on [Figure 2](#), we can conclude that the area model or area diagram is the model most often used to represent fractions, especially when it comes to part-whole relationships. These models help students see fractions as parts of wholes. Number lines, on the other hand, are used to help students understand the magnitude and order of fractions, which is important for learning about equality and basic mathematical processes such as addition and subtraction. The set model is applied in problems where fractions represent groups of objects, assisting students in transitioning from discrete to continuous concepts of fractions. Finally, the bar model or tape diagram is utilized in comparative fraction problems, making it easier for students to visualize proportional relationships.

This variety of representations highlights the importance of considering the problem context when choosing the most effective visual aid for student comprehension. Specifically, model areas and number lines foster conceptual understanding, while bar models and set models may be more effective in applied or comparative fraction tasks.

Table 5. Synthesis of visual representation impact on fraction problem-solving

Visual representation types	Studies	Impact
Diagrams & Geometric Models (partitioning, shading, area models)	(Arianto & Supardi, 2024; Chususiyah et al., 2021; Cramer et al., 2019; Fang et al., 2023; Hidayatullah et al., 2024; Hwang et al., 2023; Imaniyah & Fiantika, 2024; Jiang, 2021; Kamid et al., 2023; Mahama & Kyeremeh, 2023; Pearn et al., 2018; Suryaningrum et al., 2020; Valenzuela-Ochoa et al., 2023; Widjaja et al., 2025)	Enhances conceptual understanding and fraction comparison. However, over-reliance may hinder generalization and algebraic thinking.
Number line	(Cramer et al., 2019; Jiang, 2021; Khoo et al., 2025; Valenzuela-Ochoa et al., 2023)	Improves fraction problem-solving when appropriately guided but can cause misinterpretation without prior experience.
Set model (grouping & manipulatives)	(Jiang, 2021)	Strengthens conceptualization of fractions as groups or collections. It is effective in early learning stages but less intuitive for complex fraction operations.
Bar model (tape diagrams)	(Fang et al., 2023; Kamid et al., 2023; Mahama & Kyeremeh, 2023)	Supports the visualization of fraction equivalence, comparisons, and operations. Also, it helps bridge concrete to abstract thinking but requires structured instruction to prevent misconceptions.

The studies reviewed generally suggest that visual representations are associated with students' ability to solve fraction word problems, although the strength of this relationship varies across studies. Various types of visual aids, such as diagram models, number lines, set models, and bar models, have different impacts depending on the student's prior knowledge and the complexity of the fraction problem.

Discussion

The role of visual representation on fraction problem-solving

Consistent with earlier empirical findings on the benefits of visual representations in fraction word problems, the results of this study indicate that visuals function as a mediating tool that supports students' semiotic coordination between the problem situation, the constructed representation, and the intended mathematical meaning (see Table 5). Along with these, some research also noted that visual aids help students make mental models of problems that make routine and multi-step problem-solving easier (Colonnese et al., 2026; Jitendra & Woodward, 2019). Students can understand word problems that require fraction operations or comparisons by using visual representations to see how different fractions relate to each other (Valenzuela-Ochoa et al., 2023). Nevertheless, studies show that only 25.9% of students can answer fractional word problems accurately, indicating difficulties in mathematical language and its representation (Agusfianuddin et al., 2024). It has been identified that primary students often struggle more with verbal problems compared to symbolic or numerical formats (Çimen & Kartal, 2021). This issue comes from the complex process of translating verbal representation into mathematical ideas, which makes it hard to understand and solve fraction-related problems (Chan & Kwan, 2021; Fuchs et al., 2020).

Empirical evidence where students fail to leverage visual representations effectively is demonstrated by phenomena in field practices as found by Suryaningrum et al. (2020); students who knew how to use visual aids properly missed important details, which led them to incorrect conclusions about a problem involving the distribution of portions in the fractional word problem. This phenomenon emphasizes the necessity of incorporating visual tools and guiding students in recognizing essential elements within problems. Incorporating visual representations such as diagrams or models may support comprehension and facilitate more effective problem-solving strategies. These tools promote using varied strategies, like partitioning and scaling, rather than rote memorization. It emphasizes the importance of understanding how cognitive resources, including working memory, contribute to individual differences in problem-solving accuracy. It suggests that interventions to compensate for working memory limitations or building capacity can also positively affect accuracy (Fuchs et al., 2020). Building on this statement, visual aids are suggested to reduce cognitive load by simplifying complex fractional ideas. Enabling students to focus on the mathematical relationships instead of being overwhelmed by numerical calculations (Arianto & Supardi, 2024; Aryanti, 2023; Cramer et al., 2019; Fang et al., 2023; Hidayatullah et al., 2024; Hwang et al., 2023; Imaniyah & Fiantika, 2024; Pearn et al., 2018; Suryaningrum et al., 2020; Valenzuela-Ochoa et al., 2023).

Here, area models or area diagrams are used the most because their simple layout makes working with fractions simpler and may reduce mental effort. Similarly, bar models positively affect students' accuracy in solving word problems (Shah, 2022). This may occur because bar models help break down multi-step problems into visual segments. Visual tools such as number lines and bar models are often reported to support problem-solving processes, particularly when introduced with appropriate guidance. When introduced with proper guidance, number lines understand fractions as measurements and solve problems involving ordering or operations. However, without prior experience, they may not understand them correctly, which can lead to mistakes. Bar models help students think about real and abstract ideas. Bar models help them visualize word problems (such as “half of a ribbon”) and relate them to mathematical operations. Its organized layout allows for step-by-step reasoning, which makes it easier to solve difficult situations.

It is important to note that these visual tools can help students learn, but only if used correctly with proper guidance, and they depend significantly on students' familiarity with them. Number lines, for example, may increase the cognitive load if students lack foundational training in interpreting intervals. As noted by Jitendra & Woodward (2019), the limitations of ready-made diagrams become clearer when problems become more complex. This shows that students may not be able to use visual aids well if they do not know how to read and use diagrams every day in class. A structured scaffold is needed to ensure that visual aids such as diagram models, bar models, or number lines ease the mental load on students instead of making things more difficult.

Impact of visual representation on fraction conceptual understanding

Visual representations are widely reported to support students' conceptual understanding of fractions (Khoo et al., 2025; Van Lieshout & Xenidou-Dervou, 2020). This enhancement primarily stems from the use of diagrams and geometric models, such as area models, partitioning, and shading, which have been the most frequently studied tools in this context. The concrete spatial context makes abstract ideas more accessible, so these visual representations may help students' understanding of basic ideas such as fraction comparison, equivalence, and part-whole relationships. For example, the graph area shaded (GAS) helps students see fractions as part of a whole, thus reinforcing their conceptual understanding of fractions as part of a whole. In addition, the set model (grouping of objects) reinforces the initial conceptualization of fractions as “collections,” but its application in research is still limited compared to the area model. The bar model (tape diagram) also contributes to conceptual understanding by illustrating equality and operations; however, this model requires structured instruction to ensure clarity and prevent misconceptions. Without carefully structured instruction, students may misinterpret segment lengths or focus on surface features rather than underlying relationships, leading to misconceptions. Therefore, although the use of various visual representations will help students to develop a better knowledge of abstract concepts in mathematics, their effectiveness is not universal and depends on representational alignment with task demands, instructional guidance, and students' prior knowledge.

Visual representation facilitates the construction of fractional meanings by providing a concrete display connected to the student's experience. Associated with real-world problem contexts, such as dividing cake or analyzing ratios, it allows students to connect mathematical concepts with practical applications in everyday life, which in turn improves their conceptual understanding of fractions (Ha, 2025; Valenzuela-Ochoa et al., 2023). This relationship between abstract concepts and real experiences is very important in making fraction ideas easier for students to understand. Along the same line, Cramer et al. (2019) revealed that students usually complete tasks by first identifying simple fractions, which indicates that a basic understanding of fractions positively affects the accuracy of their problem-solving. Consequently, these findings suggest that students' prior knowledge, together with the complexity of fractional problems, has a significant impact on their ability to solve word problems effectively. This underlines the importance of not only teaching the concept of fractions but also providing sufficient opportunities for practical application in relevant contexts.

Although diagrams are very helpful in answering math questions, students often find it difficult to know which type of diagram corresponds to a particular type of question (Ayabe et al., 2021; Fukuda et al., 2021). This challenge highlights the importance of developing students' diagrammatic reasoning skills as part of mathematics education as a whole. Students' mathematical competence in general depends heavily on their understanding of fractions; without a strong understanding of fractions, they may experience epistemological barriers that cause problems in problem-solving (Unaenah et al., 2024). Therefore, it is important to visualize fractions through geometric diagrams to build an accurate understanding of fractions. By strategically applying visual representations, teachers can guide students toward a comprehensive understanding of fractions, which includes the concepts of part of a whole, operator, size, division, and ratio. This emphasis on visual learning not only improves students' problem-solving abilities but also provides a stronger foundation for subsequent math tasks.

Cognitive mechanism: Visual representation as a cognitive load manager

Visual representation is proposed to support problem-solving processes by helping students manage cognitive load. This process occurs on two levels. First, reducing intrinsic load through spatial schemes. Intrinsic cognitive load arises from the inherent complexity of the material (e.g., understanding that fractions are numbers whose behavior differs from integers) (Klepsch & Seufert, 2020; Sweller, 1988). Visual models, especially area models, concretize the complex relationship between the numerator and denominator into a cohesive spatial information unit. Visualizing $\frac{3}{4}$ as three shaded parts of a whole divided into four is much simpler for working memory than processing its abstract concept. This concrete property may help minimize initial mental effort, allowing students to focus on problem-solving operations.

Second, reducing germane load through dual coding. When students receive word problems (verbal information) and are encouraged to translate them into diagrams (visual information), Dual Coding Theory (DCT) is applied. This dual encoding results in parallel processing that strengthens the schema in long-term memory (Wong & Samudra, 2021). The act of connecting verbal text (e.g., "half the rope") with a visualization of a divided bar model is a process of

schema construction (germane load) that results in a stronger understanding of fractions in a real-world context, rather than mere memorization.

The findings of this review highlight the important role of visual representations in improving primary school students' understanding and problem-solving abilities related to fractions. Different mathematical representations such as area model diagrams, bar models, number lines, and set models have been shown to help students understand and work with fractional ideas (Arifin et al., 2023). In addition, the integration of visual representations and manipulative materials in the classroom has been proven effective in reducing cognitive load and deepening conceptual understanding. The abstract idea of fractions becomes more concrete because bar models and number lines clearly show the proportional representation of fractions. On the other hand, using diagrams of geometric shapes such as circles and rectangles helps students visualize fractions as part of the whole and improves their spatial understanding. As in previous research that utilized media based on visual elements, the use of simulations and illustrated storybooks for visual exploration of fractions and division operations was found to be effective in facilitating the understanding of complex mathematical concepts (Sa'adah et al., 2023).

The effectiveness of visual representation can be attributed to its ability to make abstract fractional concepts more concrete and easier to understand. Students can have a better understanding of the part-whole relationship in fractional concepts when they are shown the visual representation. Moreover, the cognitive mechanisms underlying visual representation are more than just memorizing the type or symbol of a fraction. According to Rif'at (2018), the use of visual representations encourages critical thinking and deeper understanding by encouraging students to make connections and draw conclusions. This cognitive engagement is critical in complex problem-solving scenarios where students must extract relevant details from representations and integrate them into their reasoning processes to arrive at solutions.

These results are consistent with the Cognitive Load Theory, which holds that visual aids reduce the mental workload required to process complex information, freeing students to focus on solving problems rather than struggle with abstract ideas (Sweller, 1988). Research has consistently shown that visual aids can enhance students' problem-solving abilities. For instance, Ocampo & Del Rosario (2022) found that using translation-based instructional materials that included visual representations significantly improved students' problem-solving skills in mathematics. This aligns with the findings of Wardani et al. (2024), who emphasized the importance of visual aids in helping students understand and solve fraction problems. As the results of research by Dewi et al. (2025) emphasize, a good visual presentation supported by appropriate language can help minimize misconceptions of mathematical concepts.

The area model dominated the reviewed studies due to its unparalleled effectiveness in introducing the most fundamental fraction concepts, specifically the part-whole sub-construct, and also demonstrating the fundamental concept of fractions regarding equal partitioning. This direct visualization is effective in addressing initial misunderstandings and optimally reducing intrinsic cognitive load during the recognition stage. However, a synthesis of cognitive literature shows that the area model has low fidelity for more advanced concepts, such as the magnitude

of fractions (e.g., accurately comparing $\frac{1}{3}$ and $\frac{3}{4}$) and fraction operations (such as fraction division). This is because the area model represents quantity in two dimensions, which complicates comparisons when the whole is not spatially identical.

The strength of this systematic literature review (SLR) lies in its use of rigorous methodology, guided by the PRISMA framework, and the adaptation of the SPIDER framework for qualitative and mixed-methods reviews. However, this study has several limitations, including the restriction of its scope to three specific electronic databases (Semantic Scholar, ERIC, and Scopus) and the inclusion of only English and Indonesian articles, which may lead to database bias and linguistic bias. Another limitation is the exclusive focus on the context of elementary school students (ages 7–12) and the heterogeneity of the included study designs, which prevented quantitative meta-analysis.

Conclusion

This systematic review suggests that visual representations are associated with improved conceptual understanding of fractions and students' ability to solve word problems. The evidence, primarily derived from studies utilizing area diagram models, indicates that these visual aids help students grasp basic concepts such as fraction comparison, equivalence, and part-whole relationships by making abstract ideas more concrete. While the synthesis of 28 studies supports the association between visual representations and improved problem-solving, it is important to note that the strength of this evidence varies. The quality appraisal revealed that the body of literature includes studies of varying methodological rigor, and the effectiveness of specific representations like bar models and number lines appears to be highly dependent on structured instructional guidance. Therefore, while the findings are promising and align with theoretical frameworks like Cognitive Load Theory, they should be interpreted with an awareness of these limitations. Future research with more rigorous designs is needed to strengthen the causal claims regarding the impact of specific visual representations on fraction learning.

Recommendation

To optimize the use of visual representations in teaching fractions, educators can adopt a multifaceted approach that pays attention to the diversity of visual aids and the specific needs of students. First, educators can diversify the types of visual models to be used in the classroom based on initial ability, complexity, and the context of the problem at hand, such as area models for part-whole relationships, bar models, and number lines for interpreting quantities. Furthermore, educators can integrate real-world contexts into fractional problems, such as sharing food or measuring length, which can strengthen the relationship between abstract mathematical concepts and students' life experiences so that these fractional concepts can be more easily understood and accessed by students.

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