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Addressing fraction comprehension: global perspectives and Malaysian educational strategies

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ABSTRACT

Understanding fractions is a significant challenge in mathematics education globally, including in Malaysia, where students often struggle with core concepts. These difficulties hinder their progression into advanced areas like ratios, proportions, and algebra. This paper proposes a conceptual framework to enhance students' understanding of fractions, with a focus on the Malaysian education system. Drawing on literature and practices from international contexts, this paper emphasizes the importance of visual models, manipulatives, technology integration and real-world applications in teaching fractions. As a concept paper, it synthesizes key insights from educational theories to develop strategies for improving fraction education. The framework highlights the need for alignment with both local and international curriculum. Key findings suggest that the use of manipulatives, visual models and technology can significantly improve fraction comprehension. By comparing global strategies, this paper offers insights into how these methods can be adapted to diverse learning environments, including low-resource settings. The framework implies that curriculum reforms, professional development for teachers and revised assessments are crucial to enhancing student outcomes in fraction education.

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1. INTRODUCTION

Mathematics education globally recognizes fractions as an essential element, playing a vital role in paving the way for a deeper understanding of complex mathematical principles such as ratios, proportions, decimals and percentages. Despite their critical role, students often find fractions challenging to grasp. This issue goes beyond any single education system and is a commonly acknowledged challenge in various educational and cultural settings around the world [1]–[4]. In Malaysia, the Standard Curriculum for Primary Schools (KSSR) emphasizes fractions as a key subject from year 1 to year 6, with the expectation that students will acquire proficiency in both conceptual and operational aspects of fractions [5].

The challenge of mastering fractions is not limited to Malaysia; it is a common issue worldwide. Studies indicate that students often have difficulties transitioning from whole numbers to fractions, leading to conceptual misunderstandings, such as the belief that multiplying fractions increase their value, based on their experience with whole numbers [6]–[8]. Azmi *et al.* [9] found that Malaysian students demonstrated low fraction number sense, which was closely linked to their overall poor performance in mathematics. This issue is mirrored in international studies, including the United States, where the National Assessment of Educational Progress (NAEP) consistently shows lower performance in fraction-related tasks compared to other mathematical areas [10].

These persistent challenges in fraction comprehension affect not only students' performance in mathematics but also their ability to apply mathematical concepts in real-life situations [11]–[14]. Without addressing these challenges early on, students may face difficulties in more advanced topics such as algebra and geometry [15]. Thus, the gap between procedural fluency and conceptual understanding needs to be addressed through innovative teaching strategies that help students build a solid understanding of fractions [16].

This paper explores both global and local (Malaysian) challenges students face in learning fractions and proposes effective strategies for improving fraction comprehension. Specifically, it addresses the research question: what are the most effective teaching methods and strategies for improving students' conceptual understanding of fractions? The proposed solution is a comprehensive framework that integrates visual models, manipulatives and technology into fraction instruction. These strategies, drawn from international best practices and adapted to local needs, offer a tailored approach to enhancing fraction learning in Malaysia.

The novelty of this study lies in its synthesis of global perspectives with local educational strategies. By drawing on existing literature and recent studies, the findings provide valuable insights for educators and policymakers, offering a practical roadmap for improving fraction instruction. The integration of visual models, manipulatives and technology is not only essential for enhancing students' conceptual understanding but also for aligning teaching methods with the demands of modern educational systems [17], [18].

2. INSIGHTS INTO FRACTION EDUCATION

Grasping the concept of fractions is a well-known hurdle in the field of mathematics education, underscoring it is vital role. Numerous studies have explored what makes fractions particularly challenging for students, with scholars agreeing that their abstract nature requires a shift in understanding that can be overwhelming for many learners [3], [4]. This overview highlights crucial research concerning the struggles students face with fractions and the suggested strategies to address these issues.

A pivotal contribution to this topic was made by Siegler *et al.* [19], who pointed out the intricate notions encompassing fractions, such as the ideas of part to whole, equivalency and fraction operations. Their work revealed that students frequently lack a deep grasp of these concepts, leading to enduring mistakes when working with fractions. Without a solid foundation in fraction concepts, students may resort to memorization or incorrect procedural methods, leading to systematic errors in their mathematical reasoning [20], [21]. This study has underpinned a lot of the continuing examination into how fractions are learned. Subsequent research by Jiang *et al.* [22] confirmed these observations, finding that students often fall back on reasoning based on whole numbers in fractional contexts, which can cause consistent missteps. For instance, a common error among students is the misunderstanding that a fraction with a bigger numerator is always greater, a misconception that becomes noticeable as they shift from whole number calculations to fraction operations [23], [24]. A key problem identified is that students often find it difficult to develop a comprehensive conceptual understanding of fractions, which is essential for properly executing algorithms [17].

The significance of a conceptual grasp is emphasized further in Obersteiner *et al.* [25] investigation into the cognitive challenges students face with fractions. They identified that numerous students cling to flawed yet intuitive beliefs about fractions, such as the notion that multiplication of fractions invariably increases the value. Such misconceptions are rooted in a fundamental misunderstanding of fraction concepts, further complicating students' ability to perform fraction operations correctly [26]. These deep-seated misconceptions prove hard to correct, particularly when traditional teaching focuses more on memorization than on understanding concepts [27]. More recently, Braithwaite and Siegler [28] investigated how understanding whole numbers and fractions develop together. They suggest that students struggling with fractions often do not firmly grasp how whole numbers and fractions differ conceptually. This lack of understanding can pose hurdles not just in learning fractions but also in tackling more complex mathematical areas like algebra and geometry. The critical divide in comprehension between whole numbers and fractions represents a significant hurdle [29].

To address the conceptual challenges in fraction comprehension, recent research has shifted towards more interactive and multi-modal strategies that emphasize conceptual understanding over procedural fluency. Wilkie and Roche [30] offer valuable insights into the preferred strategies used by primary teachers for teaching fractions. The study emphasizes the importance of choosing appropriate fraction models and manipulatives that align with students' conceptual development. This approach reflects broader recommendations in the literature, as other studies, such as Karika and Csíkos [31], also highlight the critical role of visual representations in enhancing students' understanding of fractions. The preferred models and manipulatives are summarized in Table 1.

Table 1. Preferred fraction models for enhancing fraction comprehension

Category	Model/tool	Description
Fraction models for teaching	Set models	Teachers favor set models as they help students visualize fractions as collections of discrete objects, making part-whole relationships easier to understand.
	Rectangle models	Rectangle models are useful for dividing into equal parts, helping students understand fraction equivalence and the significance of numerators and denominators.
Use of manipulatives	Fraction bars	Fraction bars effectively show fractions in a linear format, useful for teaching equivalence and integration with number lines.
	Cuisenaire rods and geoboards	Tactile tools like Cuisenaire rods and geoboards offer hands-on learning experiences, helping students understand more complex concepts like mixed numbers and fraction multiplication.
Multi-model approach	Combined use of continuous and discrete models	Combining both rectangle (continuous) and set (discrete) models with manipulatives like fraction bars enhances students' understanding and fluency with different fraction representations.

Research by Şengül and Zora [32] further supports the use of manipulatives, demonstrating that students who use fraction bars and rods can engage more effectively with fraction-related tasks, improving their number sense. These manipulatives provide visual and tactile aids that help students grasp abstract fraction concepts, enabling them to develop a stronger foundation in mathematics. Moreover, studies like Amo-Asante and Bonyah [33] along with Vessonen *et al.* [34] highlight that manipulatives need to be integrated into a broader conceptual framework that includes problem-solving applications and active learning strategies. When used within this comprehensive approach, manipulatives not only enhance procedural knowledge but also promote deeper conceptual understanding, equipping students to apply their fraction skills to more complex mathematical problems [35].

These findings are consistent with international assessments, such as the NAEP [10], which consistently highlight that students' grasp of fractions is weaker than other areas of mathematics. In the eighth grade, many students struggled with fraction concepts, particularly when applying them to problem-solving scenarios. This issue is not confined to the United States; studies from Alshahri [36] and Kor *et al.* [37] indicate that students in Malaysia and other global contexts experience similar difficulties in mastering fraction concepts. Trujillo *et al.* [38] also note that these challenges are universal and that new teaching strategies and curriculum revisions are needed to improve fraction learning outcomes globally.

3. METHOD

This paper adopts a concept-driven approach aimed at addressing the challenges of fraction comprehension in mathematics education. Instead of conducting an empirical study or a formal literature review, the conceptual framework presented here is developed through an analysis of established educational theories and practical teaching experiences. The concept paper synthesizes insights from educational theories and recent studies, alongside the challenges faced by students in Malaysia and other global contexts, to propose a framework that aligns with both local and international curriculum requirements. The objective is to propose strategies for improving fraction comprehension by synthesizing insights from key research studies on teaching methods, both globally and within the Malaysian educational context.

To construct this framework, relevant research studies and educational reports were examined, particularly those focusing on the use of teaching strategies such as visual models, manipulatives and technology in enhancing conceptual understanding. The study also incorporates insights from Malaysia's KSSR, which highlights fraction education as a critical component of the national mathematics curriculum. The framework draws from global educational practices, including those from countries that face similar challenges in fraction education. This methodology aims to build a comprehensive, adaptable model for enhancing fraction education, grounded in theoretical insights and practical teaching strategies.

The analysis process involved synthesizing these key insights to compare and contrast various teaching strategies across different educational systems. This comparative approach allowed for the identification of common challenges and successful interventions used in diverse contexts. By focusing on both global and local (Malaysian) perspectives, the framework offers a comprehensive set of recommendations aimed at improving fraction comprehension, which can be adapted to a wide range of educational contexts.

4. IMPLICATION ON EDUCATIONAL OUTCOMES AND PRACTICES

4.1. Student outcomes

Enhancing students' grasp of fractions significantly boosts their overall success in mathematics. As a foundation for advanced mathematical concepts like ratios, proportions, percentages and algebra, fractions

are essential. A robust conceptual grasp of fractions prepares pupils for these advanced topics, thus enhancing their mathematical skill. This basic comprehension becomes crucial as students tackle more complex mathematical ideas throughout their educational journey.

Recent research underscores the importance of manipulatives in improving students' fraction comprehension. Study by Farra *et al.* [39] showed that both virtual and concrete manipulatives had a positive impact on students' learning of fraction operations, particularly in fostering a better understanding of addition and subtraction of fractions. Similarly, Şengül and Zora [32] emphasized the role of intuitive understanding developed through manipulatives, which can help bridge procedural and conceptual knowledge gaps in students. The study by Tadeu [40] also supports this view, indicating that children who use manipulatives from an early age show better long-term retention and application of fraction concepts, which is crucial for their progression in mathematics.

Additionally, Alqahtani *et al.* [41] found that preservice teachers who learned fractions through both discrete and continuous models developed a deeper understanding of how to teach these concepts effectively. This insight is critical for student outcomes, as teachers' understanding directly influences their ability to teach fractions in a way that promotes long-term retention and conceptual understanding. The impact of effective fraction instruction on student outcomes is further supported by Bruce *et al.* [42], which showed that number lines and unit fractions are particularly effective in helping students understand the part-whole relationship and equivalence, foundational concepts that support learning in more advanced mathematical areas.

Furthermore, mastering fractions has significant consequences for long-term academic achievement. Studies have repeatedly demonstrated that struggles with fractions are indicative of future difficulties in more complex mathematics topics [43]. Early intervention and equipping students with the necessary understanding of fractions can pave the way for continued success in mathematics and other science, technology, engineering, and mathematics (STEM) fields. These studies highlight that concrete experiences can solidify students' understanding of fractions, offering educators a valuable tool for enhancing students' conceptual understanding. However, further research is needed to explore how these tools impact long-term retention of fraction concepts.

4.2. Educational practices

The persistent challenges in teaching fractions underscore the limitations of traditional methods focused on rote memorization and procedure-based teaching. Research increasingly advocates for shifting toward pedagogical approaches that prioritize conceptual understanding, where students can grasp the "why" behind mathematical processes [44]. Concrete models, manipulatives and technology-based tools play pivotal roles in making abstract mathematical concepts more tangible for learners [45].

For example, recent studies have demonstrated the effectiveness of using visual aids, such as area models and number lines, to enhance students' understanding of fractional relationships [39]. This approach helps students visualize and internalize key fraction concepts, moving beyond mere procedural proficiency. Research by Alqahtani *et al.* [41] further supports the integration of both discrete and continuous models, helping students create deeper connections between different representations of fractions. This combined approach reinforces the conceptual and visual understanding of fractions, offering a more cohesive learning experience. A study by Prihantini *et al.* [44] emphasized the importance of integrating virtual manipulatives with physical models to create a blended learning environment that is both interactive and engaging. Virtual platforms, such as fraction games and simulation apps, also offer opportunities for students to apply these concepts in various scenarios, strengthening their understanding [46].

Shifting to these student-centered approaches requires educators to undergo substantial changes in their instructional techniques. Moving away from lecture-centric teaching to more exploratory and hands-on learning is necessary for fostering a deeper comprehension of fractions [47]. Research from Tadeu [40] indicates that visual tools, when used in tandem with interactive teaching, significantly enhance students' cognitive engagement with fractions, helping them transition from surface-level understanding to deeper comprehension. Fraction models, such as set models and Cuisenaire rods, have shown promise in aiding students' ability to visualize and understand fraction equivalence, as suggested by recent studies [33]. Moreover, research supports the integration of digital tools like virtual manipulatives and educational software to create more dynamic learning experiences.

This shift towards innovative fraction instruction also requires significant investment in teacher training and professional development. Teachers need consistent exposure to the latest research and tools in mathematics education, particularly in fraction instruction [48]. Ongoing professional development programs are crucial for equipping teachers with the necessary skills to integrate visual and interactive methods into their teaching repertoire. Additionally, research suggests that well-trained educators who employ diverse teaching strategies are more likely to facilitate significant improvements in students' understanding of fractions [49].

4.3. Policy implications

The need to boost fraction understanding transcends classroom boundaries, impacting educational policy domains. Given that fractions serve as a foundational element for mastering more complex mathematical concepts, it is essential for those designing curriculums to provide ample learning opportunities that tackle the nuances of fractions before students move on to more challenging areas such as ratios, proportions and algebra. This goal might necessitate a review and refresh of national math curriculums to focus more on understanding concepts rather than just memorizing procedures. For instance, the integration of more hands-on learning aids, conceptual teaching methods and practical examples in Malaysia's KSSR could significantly improve early mastery of fractions [44].

Recent studies suggest that countries with comprehensive curriculum reforms emphasizing conceptual learning over rote memorization tend to outperform others in international assessments [40]. Countries like Singapore and Finland, which have adopted such practices, have consistently ranked high in fraction comprehension and overall mathematical literacy [50]. These examples provide valuable insights into how policy adjustments can enhance national educational outcomes. Early intervention strategies are crucial. Research has shown a direct correlation between early mastery of fractions and later success in advanced mathematics and STEM fields [43]. As a result, educational policy makers should make it a priority to strengthen fraction teaching in the initial years of education and support this with continuous professional development for teachers.

Moreover, international assessments like the Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) offer useful metrics for policy makers to gauge and compare their nation's math performance, particularly in fractions. Successful countries in these assessments typically employ effective teaching methods and policies that promote critical thinking, experiential learning and the practical application of math concepts, as noted by Zhang *et al.* [51]. Leveraging the insights from high-performing countries in PISA and TIMSS, national education policies can be restructured to focus on fostering deeper understanding through practical and problem-solving approaches [41]. These success stories can serve as benchmarks for reforming fraction education.

Assessment methods also need to evolve to more accurately reflect a student's conceptual grasp of fractions, rather than just procedural prowess. Traditional testing methods often miss the mark in capturing a student's deep understanding of fractions, potentially leading to progression with a shaky foundation that could impede future mathematical achievements [52]. It is imperative to implement assessment techniques that challenge students to showcase their analytical and problem-solving skills in fraction-related scenarios and their application in real-life situations.

It is important for teachers to have access to modern teaching tools, including virtual and digital resources [30], which have been proven to enhance conceptual understanding among students. Furthermore, assessments designed to measure both procedural and conceptual skills provide better diagnostic insights into students' fraction understanding [30]. Such assessments can offer a more nuanced understanding of students' strengths and weaknesses, allowing for more targeted interventions and support in the learning process. By updating curriculum guidelines, refining assessment methods and embedding proven strategies into national educational policies, governments and educational bodies can nurture a learning environment that promotes a thorough understanding of fractions. This approach will not only enhance educational outcomes but also equip students for advanced studies in mathematics and related disciplines [53].

4.4. Future research directions

Given the ongoing issues in fraction comprehension, ongoing research into effective teaching methodologies is imperative. As the complexities of fraction comprehension continue to challenge both educators and students, there is a pressing need for further research into innovative and sustainable strategies for fraction instruction. Despite notable advancements in pinpointing successful pedagogical techniques, there's a vast opportunity to enhance learning outcomes in fraction education through innovative teaching methods and comprehensive educational reforms.

A critical area for future exploration is the creation of teaching strategies that favor deep conceptual understanding rather than just procedural knowledge. Research has shown the benefits of employing manipulatives and visual aids in closing the comprehension gaps among students [32], [39]. However, deeper investigations are required to assess how these methods affect long-term retention and mastery of fractions. For example, Naidoo and Hajaree [54] noted that while virtual manipulatives could improve immediate learning outcomes, their impact on sustained knowledge retention is yet to be fully understood. Similarly, although discrete and continuous models improve short-term comprehension, further research is needed to assess their impact on long-term mastery of fractions [41]. Future research should delve into ways of helping students move from tangible aids to abstract thinking, ensuring long-term conceptual retention.

Additionally, the role of professional development in enhancing teachers' proficiency in fraction instruction is paramount. According to Flores-Velazquez *et al.* [55], the success of using manipulatives and

digital tools largely depends on the teacher's skill in applying these resources. It is essential to focus research on designing professional development programs that equip educators with effective strategies and knowledge for fostering impactful learning experiences in fractions [56]. Moreover, tailoring these programs for teachers in economically disadvantaged areas, where access to sophisticated tools might be limited, is crucial.

When it comes to assessment, current methods often fall short of capturing students' conceptual understanding of fractions, focusing instead on procedural competence. This overlooks the comprehensive understanding students have of fraction concepts [57]. Future research should aim at developing assessment techniques that evaluate both procedural and conceptual knowledge, possibly through open-ended tasks or real-life scenarios that require students to articulate their thought processes and understanding of fractions in different situations. Such assessments could provide a deeper insight into student capabilities, leading to more precise teaching interventions.

Furthermore, there is a need for longitudinal studies that follow the progression of students' understanding of fractions from elementary through secondary education. As Tian and Siegler [52] pointed out, while many interventions show quick improvements in understanding fractions, the long-term sustainability of these improvements is often not examined. Longitudinal research could illuminate the optimal timings and methods for introducing various teaching strategies for lasting impact on students' mathematical growth. Leveraging longitudinal designs could also provide insights into when specific interventions such as the use of number lines or manipulatives are most effective for different age groups [42].

Lastly, the effect of cultural and contextual factors on fraction learning is an area that warrants more attention. Studies have indicated that students from different cultural backgrounds may employ varied approaches to solving fraction problems, influenced by their prior mathematical experiences and number systems [26]. Investigating how teaching strategies can be adapted to be culturally responsive and support the unique learning needs of students is essential. This research could lead to the development of teaching practices that respect the diverse educational backgrounds of students learning fractions.

In summary, advancing our understanding of fraction teaching requires a multidimensional research approach, focusing on teaching methodologies, professional development, assessment techniques and the influence of culture on learning. Such an approach can provide deeper insights into how students from different backgrounds grasp fraction concepts, allowing educators to tailor their strategies accordingly. These research paths promise to refine educational practices, making fraction learning more equitable, inclusive and effective, thereby better preparing students for success in mathematics and related STEM fields.

5. RECOMMENDATION

Based on the implications discussed, the following recommendations are proposed to improve fraction comprehension among students, enhance educational practices and shape policy development. These recommendations focus on instructional strategies, curriculum improvements, teacher development and further research to address common challenges in fraction learning. By implementing these evidence-based approaches, educators and policymakers can create more effective and engaging fraction instruction that supports long-term student success.

5.1. Emphasize conceptual understanding in teaching fractions

Considering the common challenges faced by students in mastering fractions, it is vital for educators to transition their emphasis from mere procedural fluency to conceptual understanding. Research shows that students often rely heavily on memorization and procedures, which limit their ability to apply fraction concepts in novel contexts [40]. Traditional teaching methods, which prioritize memorization and repetitive exercises, are insufficient for fostering a deep understanding of fractions. Instead, incorporating visual aids such as area models, number lines and set models significantly aids in helping students conceptualize fractions and understand their properties [30]. These aids become especially powerful when paired with tangible activities, enabling students to engage directly with fractions, thus fortifying their conceptual grasp. These aids, when paired with tangible activities, help students directly engage with fractions, fortifying their conceptual grasp [32]. Such pedagogical approaches should be central to fraction instruction to ensure students build a robust foundation in understanding fractions. Additionally, fraction instruction must focus on helping students transition from using manipulatives to abstract reasoning. This approach ensures that students not only understand fraction operations but also retain their conceptual knowledge over time [44].

5.2. Integrate technology into fraction instruction

Technology's role in enriching fraction instruction has been well-documented. It is advisable for teachers to integrate digital tools and interactive software into their fraction lessons. Studies have shown that online manipulatives, educational apps and smart boards provide vibrant and engaging representations of

fractions, allowing students to explore and interact with fraction concepts in a dynamic and safe environment [54], [55]. These tools also help personalize the learning experience by offering differentiated instruction based on individual student needs [41]. Technology also provides instant feedback and diverse representations, which are essential for reinforcing students' conceptual understanding. Moreover, using technology allows for the personalization of learning experiences, which can be especially beneficial in meeting the varied needs of students [44]. Future research should focus on how best to integrate these tools into regular classroom practices, especially in under-resourced environments [39].

5.3. Provide ongoing professional development for teachers

For these advanced teaching strategies to be implemented effectively, educators must receive continuous professional development. Recent research emphasizes that while tools like manipulatives and digital technology are powerful, their impact largely depends on the teacher's ability to use them effectively in the classroom [55]. Professional development initiatives should focus on equipping teachers with both the pedagogical knowledge and practical strategies needed to foster meaningful fraction learning experiences. Importantly, such programs should be adapted to the needs of teachers in low-resource settings, where access to advanced tools may be limited [17]. Training should also encourage collaboration among educators, promoting the exchange of effective practices and fostering reflective teaching. Furthermore, professional development programs should focus on building teachers' capacity to effectively combine concrete manipulatives with virtual learning tools, creating a blended learning environment [40]. Studies suggest that professional development that is sustained over time and integrated into teachers' practice has a greater likelihood of improving student outcomes [58].

5.4. Revise curriculum and develop assessments to ensure conceptual understanding

Curriculum developers are encouraged to update mathematics programs to present fractions not just as theoretical concepts but also as functional tools for addressing real-life challenges. Introducing students to practical applications and examples of fractions can make learning more tangible and intriguing, helping them recognize the practicality of their lessons [28], [53]. Activities such as calculating recipe ingredients, dividing resources in construction projects or interpreting scientific data can bridge fractions to daily scenarios, assisting students in building a profound, applicable understanding of fractions. This approach not only makes the learning process more relatable but also strengthens students' fundamental grasp of fraction concepts.

In addition to curriculum revisions, assessments should be aligned with these practical applications and focus on evaluating students' conceptual understanding rather than simply their procedural skills. Current assessment methods, which tend to focus on procedural knowledge, might not adequately reflect a student's grasp of fractions [57]. As such, educational authorities are encouraged to develop and implement assessment tools that measure students' ability to apply fractions in real-world situations and explain their reasoning. Incorporating tasks that require problem-solving in practical contexts could offer deeper insights into a student's comprehension and enable more targeted educational interventions [39]. Assessments that challenge students to think critically and demonstrate the application of fractions in practical scenarios will help cultivate a deeper and more enduring understanding of the topic.

5.5. Conduct further research on effective fraction instruction

Ongoing research is pivotal in discovering and refining the most effective methods for teaching fraction. Studies should focus on how teaching practices, technological tools and curriculum adjustments affect long-term student outcomes in fraction comprehension [59]. Furthermore, research should explore how fraction instruction can be tailored to meet the needs of diverse student populations, including those in low-resource or high-needs environments [44]. Particularly, research should focus on examining how cultural differences influence students' fraction comprehension and identifying strategies that can be adapted to local contexts [41]. Longitudinal studies are particularly important in assessing the long-term impact of these instructional interventions and how they affect students' mathematical development from primary through secondary education [60]. Research could also investigate the role of teacher professional development in enhancing the effectiveness of fraction instruction across different educational settings, ensuring equitable access to quality education.

These recommendations, when implemented, are expected to significantly enhance students' understanding of fractions and improve educational outcomes. The conceptual framework presented in this paper offers substantial practical, theoretical and methodological contributions to the field of fraction education. On a practical level, it provides educators and policymakers with actionable strategies such as the integration of manipulatives, technology and targeted professional development, all aimed at improving students' conceptual grasp of fractions. These strategies, drawn from global best practices, can be adapted across diverse educational settings to strengthen curriculum design and instructional approaches.

The theoretical contribution lies in the application of educational theories, such as constructivist approaches, to fraction instruction, enhancing our understanding of how students internalize complex mathematical concepts. By emphasizing the use of visual models, real-world applications and culturally responsive teaching, this paper advances current thinking on effective fraction education. From a methodological perspective, the paper lays the groundwork for future empirical studies, encouraging further research on how these strategies can have long-term impacts on student learning outcomes, with a focus on conceptual understanding over procedural fluency. This multidimensional framework provides a comprehensive approach to improving fraction instruction, making it an essential contribution to both practice and research.

Figure 1 provides a comprehensive framework of the key strategies discussed in this paper and their anticipated impact on fraction education. This framework emphasizes the importance of visual models, technology integration, real-world applications, professional development for teachers and revised assessment techniques. Each of these elements contributes to building a stronger foundation in fraction comprehension, which is essential for students' success in mathematics. The figure also outlines the expected outcomes of implementing these strategies, showcasing their potential impact on educational practices and student achievement.

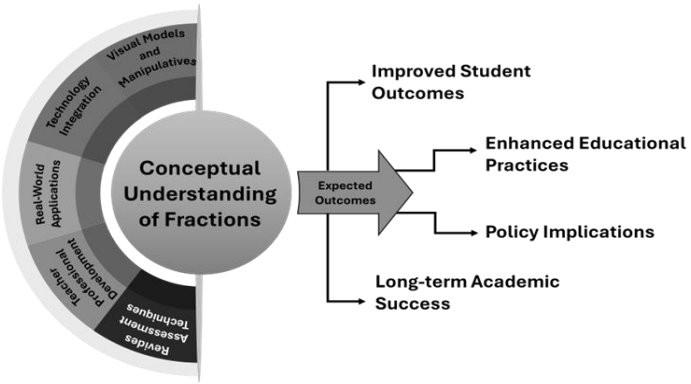

Figure 1. Conceptual framework for enhancing fraction learning

6. CONCLUSION

The struggle students face in grasping the concepts of fractions significantly impacts their overall performance in mathematics, as these challenges extend beyond any single educational system. Addressing these difficulties requires a shift from procedural fluency to a deeper, more conceptual understanding of fractions. This paper has proposed strategies such as the integration of visual models, manipulatives, technology and real-world applications to enhance fraction education. By encouraging active learning and promoting conceptual understanding, these methods have the potential to transform fraction instruction, ultimately preparing students for more advanced mathematics topics and overall academic success.

The implications of this research are substantial, particularly in the context of curriculum reform and teacher professional development. By embedding real-world applications and modern teaching tools into fraction instruction, educators can make learning more relevant and engaging for students. Additionally, ongoing professional development programs must equip teachers with the skills and resources needed to implement these strategies effectively. Continued research is also needed to examine the long-term impact of these teaching methods across diverse cultural and educational settings. Implementing these strategies can lead to a more effective and equitable approach to fraction education, benefiting students both in their immediate studies and as they pursue future success in STEM fields and beyond.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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