



Multirepresentational Fraction Comparison Learning through the Integration of Fraction Board Media and Lumi Education Interactive Digital Media

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ABSTRACT

Purpose of the study: This study aims to describe the implementation of fraction comparison instruction based on multiple representations through the integration of concrete manipulatives and interactive digital media within a creative STEAM education framework, as well as to examine how this process supports the development of participants' conceptual understanding and mathematical thinking strategies.

Methodology: This study employed a descriptive qualitative approach, with the research subjects being graduate students in the Master's Program in Mathematics Education who participated in peer teaching activities. Data were collected through observation, participant worksheets, and interviews, and were then qualitatively analyzed through the stages of data reduction, data presentation, and drawing conclusions using triangulation techniques

Main Findings: The results of the study indicate that multirepresentation-based learning supports participants' development of conceptual understanding in comparing fractions. Participants were not only able to solve problems procedurally but also demonstrated the ability to transform representations from concrete contexts into symbolic forms and to use formal strategies such as finding common denominators. The gradual integration of concrete and digital media facilitated the transition in thinking from the concrete to the abstract, while visualizations and feedback in digital media helped reinforce participants' understanding and reflection.

Novelty/Originality of this study: This study proposes a multi-representation learning approach that integrates concrete and interactive digital media within a creative STEAM education context, and places the transformation of representations at the center of its analysis of the development of mathematical thinking strategies. Furthermore, the use of peer teaching contexts offers a new perspective for exploring the learning process in mathematics in a reflective and conceptual manner.

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1. INTRODUCTION

Understanding fractions is a fundamental component of mathematics education, as it serves as a prerequisite for various advanced topics such as ratios, percentages, algebra, and more complex mathematical operations. Various classical and contemporary studies have shown that mastery of fraction concepts has a strong correlation with student success in subsequent stages of mathematics learning [1]–[3]. Therefore, the quality of fraction instruction remains a crucial issue in mathematics education in schools.

However, extensive international research indicates that fractions are among the most difficult mathematical concepts for students to grasp. These difficulties persist even after years of formal instruction and often continue into secondary school [4]–[6]. These findings suggest that the challenges in learning fractions are fundamental and cannot be explained solely by a lack of procedural practice.

Cognitive research reveals that students' difficulties in understanding fractions are primarily conceptual in nature. Students often struggle to interpret the relationship between the numerator and denominator, to understand fractions as whole numerical quantities, and to meaningfully relate parts to the whole [7]–[9]. One of the most common misconceptions is the whole-number bias, which is the tendency for students to apply whole-number reasoning when dealing with fractions; for example, assuming that a fraction with a larger denominator always has a larger value [8], [10]. These findings are also supported by research showing that learning fractions requires a balance between conceptual and procedural understanding so that students can develop a deeper understanding [11], [12].

Difficulties in understanding fractions are not limited to an international context but are also consistently reported in studies conducted in developing countries. Research indicates that misunderstandings formed during early education tend to persist and negatively impact students' ability to learn advanced mathematical concepts, including algebra and proportional reasoning [6], [13]. This underscores the importance of teaching fractions in a way that emphasizes conceptual understanding from the very beginning.

One factor contributing to the persistence of misunderstandings about fractions is a teaching approach that predominantly emphasizes symbolic manipulation and procedural calculations, while the reinforcement of meaning through diverse representations has not yet been adequately integrated. Duval argues that mathematical understanding cannot be built through a single system of representation. Instead, it requires students to coordinate and transform various representations in a meaningful way [14], [15]. When students fail to connect concrete, visual, and symbolic representations, mathematical symbols tend to be processed mechanically without deep conceptual understanding.

In line with this perspective, a multirepresentational learning approach is considered an effective strategy for supporting conceptual understanding in mathematics. Ainsworth explains that multiple representations serve complementary functions, limit misunderstandings, and foster deeper understanding, provided that the relationships among these representations are explicitly guided by the teacher [16]. In fraction learning, integrating concrete, visual, and symbolic representations allows students to develop a more flexible understanding and reduces the risk of divided attention [14], [16]. Concrete manipulatives have long been recognized for their role in helping students build mathematical understanding through direct experience and visual exploration [1], [3]. However, some studies suggest that the use of concrete manipulatives alone does not always guarantee strong symbolic understanding, especially when the transition to formal representations is not systematically designed [9].

Advances in digital technology offer opportunities to enhance multirepresentational learning through dynamic visualization, direct interaction, and immediate feedback. Research indicates that technology-supported learning environments can facilitate student reflection, exploration of various representations, and the gradual development of conceptual understanding [17], [18]. Furthermore, the use of audiovisual media that integrates visual and verbal elements has also been shown to significantly improve student understanding [19], [20]. However, the use of technology in mathematics education is often not conceptually connected to students' concrete learning experiences, resulting in the underutilization of technology's potential to foster coherent understanding [18], [21].

Within the framework of Creative STEAM Education, mathematics learning is viewed as a space for integrating creativity, cross-representational thinking, and the meaningful use of technology. STEAM is not merely understood as a combination of disciplines or the use of technology, but rather as a pedagogical approach that emphasizes conceptual integration, creative thinking processes, and

contextual problem-solving [21], [22], [23]. The integration of artistic elements into STEAM also contributes to enhancing creativity and innovation in mathematics learning [24]. Creativity in mathematics learning is reflected in students' ability to explore various representations, strategies, and explanations in understanding a concept [25].

To strengthen the theoretical foundation of this approach, an understanding is needed of how students process and transform various representations in mathematics learning. From a cognitive perspective, mathematical activities rely heavily on the use of semiotic representations and the ability to transform between them [14], [15]. Furthermore, representations and visualizations are central to mathematical thinking, particularly when information is presented through a combination of visual and verbal channels simultaneously [14], [26].

From a cognitive development perspective, Bruner argues that mathematics instruction should be presented through three stages of representation—enactive, iconic, and symbolic—so that students can gradually grasp concepts, moving from the concrete to the abstract [27], [28].

In addition, cognitive load theory explains that the limited capacity of working memory can affect learning effectiveness, especially when students are presented with complex information without adequate representational support [29], [30]. Therefore, the use of structured, visual, and interactive learning media is essential to help students manage cognitive load and build more meaningful understanding [31], [32].

As technology advances, digital learning media have also proven effective in enhancing student engagement and understanding, particularly with abstract concepts such as fractions [16], [20], [32]. The integration of concrete and digital media in instruction provides opportunities to create more comprehensive learning experiences and foster deeper mathematical thinking among students.

Although various studies have demonstrated the importance of using representations in fraction learning and the potential of technology to enhance conceptual understanding, most research still views the use of concrete and digital media in isolation. Furthermore, the integration of a multi-representation approach with the STEAM education framework—which emphasizes creativity and cross-representational thinking—has yet to be explored in depth. Based on observations in the learning context, participants still struggle to consistently connect concrete, visual, and symbolic representations, particularly when understanding fraction comparisons.

Therefore, a learning approach is needed that not only combines various forms of representation but also systematically integrates concrete and digital media within the STEAM framework to support a meaningful transformation of representations. This study specifically aims to address this gap by examining the implementation of multirepresentation-based fraction comparison learning through the integration of concrete and interactive digital media within the STEAM framework, with a primary focus on the process of representational transformation as the central focus of the learning analysis.

2. RESEARCH METHOD

This study employs a descriptive qualitative approach aimed at describing the implementation of multirepresentational fraction learning through the integration of concrete manipulatives and interactive digital media within a creative STEAM education framework. The focus of this study lies on the learning process, participant engagement, and the characteristics of conceptual understanding that emerge during learning activities.

The study was conducted within the context of the Master's program in Mathematics Education. The research subjects were graduate students who served as participants in peer teaching activities. The participants acted as representatives of prospective teachers in exploring learning processes relevant to the elementary school context. This activity was designed as a learning simulation to explore how participants construct and understand the concept of fraction comparison through a multirepresentation approach.

The research procedure consists of three stages: planning, implementation, and reflection. During the planning stage, the researcher developed instructional materials and prepared the media to be used. The implementation stage involved teaching fraction comparison using a multi-representation approach, integrating concrete and digital media sequentially. Concrete media, such as a fraction comparison board, were used to facilitate initial understanding through hands-on experience. Next, interactive digital media based on Lumi Education (H5P) is used to present visual and symbolic

representations and provide immediate feedback on participants' answers. The reflection stage is conducted to review the learning process and identify the forms of understanding that emerge during the activity.

The data collection instruments used in this study included observation sheets, participant worksheets, and interview guidelines. The observation sheets were used to observe participant engagement during the learning process; the worksheets were used to analyze participants' strategies and understanding when comparing fractions; and the interviews were used to gather information about participants' responses to the use of instructional media.

Data analysis was conducted qualitatively through the stages of data reduction, data presentation, and drawing conclusions. Data obtained from observations, worksheets, and interviews were analyzed using triangulation to obtain a comprehensive picture of the learning process and the development of participants' understanding.

3. RESULTS AND DISCUSSION

Result Research

a. Learning Media Display

The teaching of fraction comparisons is carried out through the integration of concrete and interactive digital media. Concrete media, in the form of a fraction comparison board, is used to visualize the relationship between parts and the whole using a model of a circle divided into several equal parts. This medium allows students to directly observe and visually compare the values of fractions.

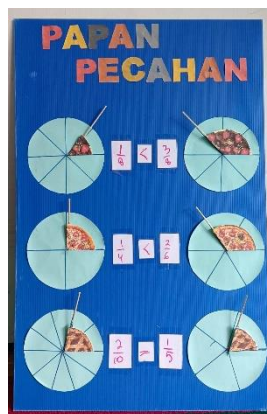


Figure 1. Fraction Comparison Board as a Concrete Manipulative

In addition, an interactive digital platform based on Lumi Education is used, which dynamically presents visual and symbolic representations of fractions. This platform features fraction comparison activities and provides immediate feedback on participants' answers, thereby supporting independent exploration and reflection.



Figure 2. Interface of the Lumi Education-Based Interactive Digital Media

b. Participants' Work

Analysis of the participants' worksheets shows that they were able to compare fractions both in situational contexts and in symbolic form. In one task, participants were asked to compare the fractions

1/4 and 2/6. Participants were able to determine that $1/4 < 2/6$ and provide a reason that 1/4 is smaller than 2/6. Additionally, in another task, participants also demonstrated the ability to use more formal strategies, such as finding a common denominator to compare fractions with different

$$\frac{1}{4} < \frac{2}{6} \text{ . jadi potongan yang harus dibeli yaitu } \frac{1}{4} \text{ karena}$$

$$\frac{1}{4} \text{ lebih kecil dari } \frac{2}{6}$$

denominators.

Figure 3. Participants' Work

c. Participants' Responses to the Learning Experience

Participants' responses indicated that the use of concrete and digital media helped them understand the concept of comparing fractions more clearly. One participant stated: "It's easier to understand because I can see the fractions directly, so I know which one is larger." Another participant also noted: "With the Lumi platform, if I make a mistake, I can correct it immediately, so I understand the process better." These responses indicate that concrete materials help participants grasp concepts visually, while digital media supports the learning process through immediate feedback.

Discussion

The research findings indicate that participants were not only able to solve fraction comparison problems but also underwent a process of representational transformation in understanding the concept. This is evident in the participants' ability to compare fractions, such as 1/4 and 2/6, and to provide logical reasoning for the results of those comparisons. In fact, some participants employed formal strategies such as finding a common denominator, indicating a shift in understanding from intuitive to procedural.

From the perspective of representation theory, these findings can be explained by Duval's theory, which states that mathematical understanding occurs through a process of transformation between representations [14]. This process involves the ability to deconstruct initial information, coordinate relationships between representations, construct target representations, and determine equivalences between representations. In this study, this process was observed when students examined a concrete context involving food portions, then identified fractional parts, and finally wrote them down and compared them in symbolic form. This indicates that students not only understand concepts procedurally but are also able to meaningfully coordinate various forms of representation.

This process of representational transformation occurs gradually through the use of learning media. This aligns with Bruner's theory, which states that learning occurs through three stages: enactive, iconic, and symbolic [27], [28]. In this study, the enactive stage was observed when participants interacted directly with concrete media in the form of a fraction comparison board. The iconic stage emerged when participants observed visualizations of fractions through digital media, while the symbolic stage was demonstrated through the participants' ability to write and compare fractions mathematically. Thus, the integrated use of concrete and digital media facilitated the transition of participants' thinking from the concrete to the abstract.

Furthermore, the presentation of concepts through various forms of representation is supported by the Dual Coding Theory, which states that information is more easily understood when presented through a combination of visual and verbal channels simultaneously [26]. In this study, the visualization of fractions using concrete boards and digital media helped students understand the relationship between parts and the whole, as well as connect them to mathematical symbols. This is also consistent with the participants' responses, who stated that they found it easier to understand the concept because they could directly see the visual representation of fractions.

Furthermore, the presence of immediate feedback in digital media also plays a role in supporting participants' learning process. From the perspective of Cognitive Load Theory, the presentation of structured information and immediate feedback can help reduce irrelevant cognitive load, allowing participants to focus more on understanding key concepts [29], [30]. This is evident from participants'

responses, who stated that they could immediately identify their mistakes and correct them through digital media. Thus, feedback serves not only as a means of correction but also as a tool for reflection that reinforces understanding.

Overall, the integration of concrete and digital media in this study demonstrates that multirepresentational learning can support the development of participants' thinking strategies. Concrete media play a role in building initial understanding through direct experience, visual media reinforce representations, and digital media, with feedback, aid the process of reflection and conceptual reinforcement. Thus, learning focuses not only on the final outcome but also on the participants' thinking processes in transforming various mathematical representations.

These findings confirm that the use of various forms of representation in mathematics instruction is not merely a matter of varying media, but rather a primary means of fostering participants' deep conceptual understanding. However, the effectiveness of instruction still depends on the teacher's role in facilitating connections between representations. Therefore, teachers need to actively guide participants so that they can meaningfully connect concrete, visual, and symbolic representations during the learning process.

4. CONCLUSION

This study demonstrates that teaching the comparison of fractions using a multi-representation approach through the integration of concrete and interactive digital media—can foster a deeper conceptual understanding among participants. Participants were not only able to solve problems procedurally but also demonstrated the ability to transform various representations, ranging from concrete contexts to symbolic forms. A step-by-step learning process that incorporates both concrete and digital media has been shown to facilitate the transition from concrete to abstract thinking. The integration of visualization and feedback in digital media also plays a role in reinforcing understanding and helping participants reflect on and refine the problem-solving strategies they use.

These findings confirm that multi-representation-based learning not only improves learning outcomes but also plays a crucial role in developing mathematical thinking strategies through the coordination of different representations. Thus, the integrated use of concrete and digital media can serve as an effective alternative learning approach to support meaningful understanding of mathematical concepts. The implications of this study are the need for mathematics instruction that explicitly integrates various forms of representation and makes meaningful use of digital media. Future research could examine the implementation of this approach in school settings to assess its direct impact on students.

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