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Enhancing Elementary School Students' Understanding of Fraction Concepts through Fraction Tower Challenge Game

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Abstract: Conceptual understanding of fractions is a key competency in elementary mathematics, yet many students rely on memorized procedures that do not support flexible reasoning. This study aimed to improve third-grade students' conceptual understanding of fractions through the Fraction Tower Challenge, a non-digital game that uses wooden fraction blocks. The study also described how students' mastery changed across two cycles that differed in grouping structure, with collaborative groups in Cycle 1 and individual activity in Cycle 2. A Classroom Action Research design with two cycles was used, and each cycle consisted of planning, implementation, observation, and reflection. The participants were 18 third-grade students in a public elementary school. Data were collected through pre-tests and post-tests consisting of three essay questions, classroom observations, and documentation, and were analyzed descriptively. In Cycle 1, the proportion of students showing full understanding increased from 0% at the pre-test to 89% at the post-test. In Cycle 2, this proportion increased from 44% to 83%. No student remained in the insufficient understanding category after either cycle. The gain in Cycle 2 was smaller than in Cycle 1, and the proportion of students showing full understanding at the Cycle 2 pre-test was lower than at the Cycle 1 post-test. These results indicate that the Fraction Tower Challenge was associated with improved conceptual understanding in this small classroom. The absence of a comparison group limits causal interpretation. The game can be considered a concrete and visual supplement to fraction instruction in the early primary grades.

Keywords: Classroom Action Research; Conceptual Understanding; Elementary Mathematics Education; Fraction Concepts; Game-Based Learning.

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INTRODUCTION

Fractions occupy a central position in elementary mathematics because they extend students' number knowledge beyond whole numbers and prepare them for later topics such as algebra. Research by Siegler et al. (2012) found that elementary school students' knowledge of fractions and division uniquely predicted their algebra knowledge and overall mathematics achievement in high school five or six years later. This pattern remained after other forms of mathematical knowledge, general intellectual ability, working memory, and family income and education were statistically controlled. Related evidence from sixth and eighth graders shows that fraction magnitude knowledge and whole number division predicted fraction arithmetic and mathematics achievement, even after reading achievement and executive functioning were controlled (Siegler & Pyke, 2013). Cross-national evidence reported by Torbeyns et al. (2015) indicates that fraction understanding is central to mathematics achievement among students from three continents.

Despite this importance, fractions remain difficult for many children. In a study of Belgian fourth- to sixth-graders, Gabriel et al. (2013) reported that pupils appeared to master the part-whole concept, while fraction numbers and operations posed problems, and that pupils appeared to apply procedures they did not fully understand. One explanation concerns the influence of whole number knowledge. Siegler et al. (2011) proposed an integrated theory of numerical development and documented ways in which whole number understanding can distort understanding of fractions. In the Indonesian context, an analysis of TIMSS results by Wijaya (2017) indicated low conceptual understanding of fractions among fourth graders, which was discussed in relation to the opportunity to learn fractions at school. Evidence from older students points to similar concerns, because Jarrah, Wardat, et al. (2022) reported misconceptions in the addition and subtraction of fractions among seventh-grade students. Difficulties with fractions may also be accompanied by negative affect toward mathematics. According to Gabriel et al. (2013), such difficulties can lead to mathematics anxiety and affect later engagement in mathematics and science, and Dowker et al. (2016) reviewed evidence on how mathematics anxiety relates to mathematics performance.

Preliminary classroom observations and interviews with teachers at the research site showed a comparable pattern. Many students had difficulty comparing fractions,

adding fractions, and applying fractions to everyday situations. Teachers attributed these difficulties to conventional teaching methods, limited use of engaging instructional media, and few opportunities for students to experience fractions through concrete activities. Observations further indicated that many students treated fractions as symbols and relied on memorized procedures, which led to misconceptions when they compared fractions or operated on fractions with different denominators.

Concrete manipulatives are one way to address this problem. A meta-analysis of 55 studies by Carbonneau et al. (2013) reported small to moderate effects in favor of instruction with manipulatives compared with instruction that used abstract symbols only, and these effects were moderated by instructional and methodological characteristics. In a systematic review, Fyfe et al. (2014) recommended beginning with concrete materials and gradually fading to abstract representations, because concrete objects help learners interpret abstract symbols that would otherwise be opaque.

Game-based learning adds challenge, rules, and feedback to this kind of concrete activity. A meta-analysis of PreK to Grade 12 studies by Tokac et al. (2019) reported a small positive effect of game-based learning on mathematics achievement, with variation across study characteristics. Wouters et al. (2013) reported that serious games were more effective for learning than conventional instruction (d = 0.29), and that learning was higher when games were supplemented with other instructional methods, when multiple sessions were involved, and when players worked in groups. A meta-analysis by Clark et al. (2016) found that digital games enhanced learning relative to non-game conditions (average effect of 0.33) and that effects varied with game design characteristics. For digital game-based STEM education, Wang et al. (2022) synthesized 33 studies and reported a moderate overall effect on learning achievement (0.667), with a larger average effect at the primary level than at the secondary level. Systematic reviews in mathematics education point in a similar direction. Hui and Mahmud (2023) reviewed studies published from 2018 to 2022 and reported that game-based learning had positive impacts on cognitive outcomes (knowledge and mathematical skills) and affective outcomes (achievement, attitude, motivation, interest, and engagement).

Several studies have examined game-based learning for fractions specifically. In a quasi-experiment with 80 fifth graders, Jarrah, Almassri, et al. (2022) found that students who learned fractions with a digital game (ABACUS) obtained a higher post-

test mean than students in a control group, with a reported effect size of 1.12. Ninaus et al. (2017) asked eleven-year-old students to play a tablet-based game on fraction magnitude and found that effects typically observed in basic research on fraction magnitude processing were replicated in the game, which suggests that game-based environments may also support the assessment of fraction knowledge.

Taken together, these studies provide evidence on the value of manipulatives, game-based learning, and fraction magnitude understanding. The fraction-specific game studies described above were implemented in digital environments (Jarrah, Almassri, et al., 2022; Ninaus et al., 2017), and less attention has been directed toward non-digital, block-based fraction games in lower primary classrooms. Grouping structure is a further aspect that has received limited empirical attention. A systematic review of 43 articles by Hussein et al. (2022) identified the need to understand how collaborative or cooperative and competitive dynamics influence students' learning in digital game-based mathematics education. A meta-analysis by Kyndt et al. (2013) reported positive effects of cooperative learning on achievement and attitudes, and these effects varied with study domain, age level, and culture. According to Gupta (2008), peer collaboration is useful in elementary mathematics, especially in heterogeneous groups, and it complements expert instruction and individual problem solving. How grouping structure relates to learning in a manipulative-based fraction game remains underexplored, particularly in third-grade classrooms.

This study addresses this underexplored aspect by examining the Fraction Tower Challenge, a non-digital game that uses wooden fraction blocks, in a third-grade classroom. The study extends previous research by examining a block-based fraction game across two Classroom Action Research cycles that differed in grouping structure, with collaborative groups in Cycle 1 and individual activity in Cycle 2. The aim of the study was to improve third-grade students' conceptual understanding of fractions through the Fraction Tower Challenge. Specifically, the study was guided by three research questions: (1) How did students' mastery categories change from pre-test to post-test in Cycle 1, in which the Fraction Tower Challenge was implemented through collaborative group activities? (2) How did students' mastery categories change from pre-test to post-test in Cycle 2, in which the Fraction Tower Challenge was implemented through individual activities? and (3) How did the changes in students' mastery categories

compare between the two cycles, considering the shift from collaborative group activities to individual activities? The findings are intended to inform teachers who seek concrete and engaging approaches to fraction instruction, and they are interpreted with attention to the limits of a small classroom study.

METHODS

Research Design

This study used a Classroom Action Research (CAR) design, known in Indonesia as *Penelitian Tindakan Kelas*. According to Manfra (2019), action research is a systematic and intentional form of inquiry into practice that places teachers at the center of research. The study was conducted in two cycles, and each cycle followed four stages: planning, implementation, observation, and reflection. During planning, the researchers prepared lesson plans, a learning module based on the Fraction Tower Challenge, assessment instruments, and observation guidelines for recording students' participation. During implementation, learning activities were carried out according to the lesson plans, with the Fraction Tower Challenge as the main instructional medium. During observation, classroom activities, students' engagement, and challenges that arose were monitored. During reflection, the collected data were analyzed to evaluate the intervention, identify areas that needed improvement, and formulate revisions for the next cycle.

Figure 1 illustrates the research procedure across the two Classroom Action Research cycles. Each cycle followed the stages of planning, implementation, observation, and reflection. Cycle 1 involved collaborative group activities using the Fraction Tower Challenge, whereas Cycle 2 incorporated individual activities following revisions based on the reflection from Cycle 1. Written tests, classroom observations, and documentation were used to collect data, which were analyzed using quantitative and qualitative descriptive approaches.

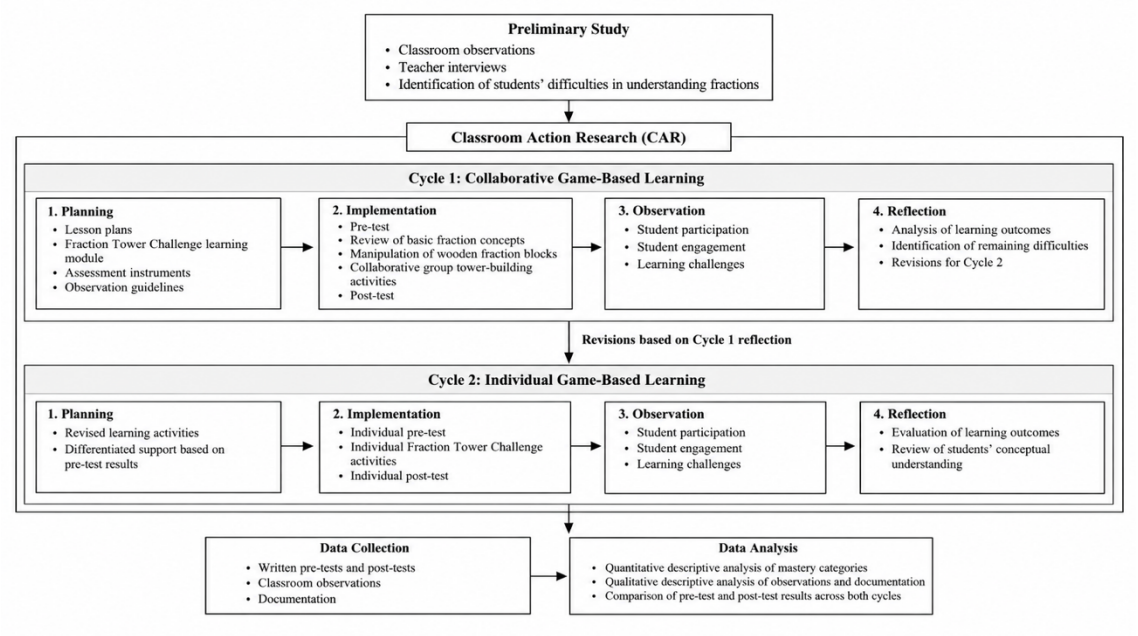


Figure 1. Research Procedure of the Classroom Action Research Using the Fraction Tower Challenge

Participants and Setting

The participants were 18 third-grade students in a public elementary school. Before the intervention, the students had received an introductory lesson on fractions. A preliminary assessment indicated that most students still had difficulty understanding relationships among fractions, identifying equivalent fractions, and representing fractions in visual and numerical forms.

The Fraction Tower Challenge

The Fraction Tower Challenge is a three-dimensional educational game that consists of wooden blocks representing different fractions. Students can touch, manipulate, assemble, and observe the blocks directly. The game addresses three content areas: recognizing different types of fractions, comparing fraction values, and understanding relationships among equivalent fractions. Students also construct towers that reach predetermined heights, which gives them a way to examine fraction addition.

Procedure

In Cycle 1, students first completed a pre-test. The teacher then reviewed basic fraction concepts through an interactive and contextual approach supported by the Fraction Tower Challenge. Students observed, manipulated, and arranged the fraction blocks, and then worked in small collaborative groups to construct fraction towers according to specific

instructions. A post-test followed the game-based activities.

In Cycle 2, the same four stages were repeated, and revisions were formulated during the reflection stage of Cycle 1. Students completed the activities individually. Each student first completed an individual pre-test, and the results provided diagnostic information that guided differentiated support for students with limited understanding. An individual post-test was administered at the end of the cycle.

Instruments and Data Collection

Preliminary classroom observations and teacher interviews were used to identify the learning problem. During the cycles, data were collected through written tests, classroom observations, and documentation. Each pre-test and post-test consisted of three essay questions that assessed students' ability to recognize fractions, compare fraction values, and solve simple contextual problems involving fractions. The post-test in Cycle 1 had a level of difficulty comparable to the pre-test and covered fraction representation, identification of equivalent fractions, and contextual problem solving. The Cycle 2 tests followed the same structure. Observation guidelines were used to record participation, engagement, and challenges during learning.

Data Analysis

Data were analyzed using quantitative and qualitative descriptive approaches. Students' test performance was classified into three mastery categories: full understanding, partial understanding, and insufficient understanding. The number and percentage of students in each category were compared between pre-test and post-test within each cycle and across cycles. Observation and documentation data were analyzed qualitatively during the reflection stage to describe students' engagement and the challenges that arose.

RESULTS

Cycle 1: Collaborative Game-Based Learning

The Cycle 1 pre-test was administered to all 18 students. The results showed that students' conceptual understanding of fractions was relatively low and had not reached the expected level of mastery. As shown in Table 1, no student demonstrated full understanding, 6 students (33%) demonstrated partial understanding, and 12 students (67%) demonstrated insufficient understanding. Many students had difficulty identifying

fractions, finding common denominators, and interpreting fractions in visual and numerical representations.

During implementation, the teacher reviewed the basic concepts of fractions and students used the blocks to observe, manipulate, and arrange fractions physically. In small groups, students constructed fraction towers according to instructions, discussed ideas, compared fraction sizes, and explored equivalent and non-equivalent fractions. Classroom observations indicated that these collaborative activities involved teamwork, communication, and shared responsibility.

The Cycle 1 post-test showed that 16 students (89%) demonstrated full understanding and 2 students (11%) demonstrated partial understanding. No student remained in the insufficient understanding category. Most students achieved higher scores than in the pre-test, particularly in representing fractions, comparing fractions, and solving simple contextual problems. The researchers nevertheless judged that the outcomes had not yet reached the predetermined success criteria, because several students still had difficulty comparing non-equivalent fractions and solving contextual problems of moderate complexity. Reflection suggested that the remaining difficulties were associated with limited opportunities for individual participation, dominance of certain group members, and confusion about equivalent fractions.

Reflection after Cycle 1 identified further issues. Some students engaged in off-task conversations during instruction, several complained about completing assignments, conceptual understanding remained relatively low for a number of students, some students forgot previously learned fraction concepts, and many students still perceived mathematics as an uninteresting subject. In response, the following revisions were introduced: increased teacher attention during instruction, more encouragement and enjoyable classroom activities, additional guidance through engaging instructional media, and efforts to foster interest in mathematics through educational games.

Cycle 2: Individual Game-Based Learning

In Cycle 2, students completed the activities individually. The individual pre-test showed that 8 students (44%) demonstrated full understanding, 7 students (39%) demonstrated partial understanding, and 3 students (17%) demonstrated insufficient understanding. The proportion of students showing full understanding was higher than at the Cycle 1 pre-test and lower than at the Cycle 1 post-test. Diagnostic information from this pre-test guided

differentiated support for students with limited understanding. Because the learning objectives had not yet been achieved consistently across all students, the intervention continued with individual rather than group activities, which gave students more opportunities for personal exploration and reflection.

The Cycle 2 post-test showed that 15 students (83%) demonstrated full understanding and 3 students (17%) demonstrated partial understanding. No student remained in the insufficient understanding category.

Comparison across Cycles

Table 1 presents the distribution of students' mastery categories across the four assessment points. The proportion of students demonstrating full understanding increased from 0% to 89% in Cycle 1 and from 44% to 83% in Cycle 2. The corresponding changes in partial and insufficient understanding are summarized in Table 2. The comparison shows that the proportion of students demonstrating full understanding increased in both cycles, while no students remained in the insufficient understanding category at either post-test.

Table 1. Distribution of students' mastery categories in each cycle (N = 18)

Test	Full understanding	Partial understanding	Insufficient understanding
Cycle 1 pre-test	0 (0%)	6 (33%)	12 (67%)
Cycle 1 post-test	16 (89%)	2 (11%)	0 (0%)
Cycle 2 pre-test	8 (44%)	7 (39%)	3 (17%)
Cycle 2 post-test	15 (83%)	3 (17%)	0 (0%)

Note. Frequencies were calculated from the reported percentages.

To provide a more detailed comparison of learning outcomes, Table 2 summarizes the changes in the distribution of students across the three mastery categories from pre-test to post-test in each cycle. The changes are expressed in percentage points to show the direction and magnitude of the shifts in students' conceptual understanding.

Table 2. Changes in Students' Mastery Categories from Pre-test to Post-test in Each Cycle (N = 18)

Cycle	Mastery category	Pre-test n (%)	Post-test n (%)	Change (percentage points)
Cycle 1	Full understanding	0 (0%)	16 (89%)	+89
Cycle 1	Partial understanding	6 (33%)	2 (11%)	-22
Cycle 1	Insufficient understanding	12 (67%)	0 (0%)	-67
Cycle 2	Full understanding	8 (44%)	15 (83%)	+39
Cycle 2	Partial understanding	7 (39%)	3 (17%)	-22
Cycle 2	Insufficient understanding	3 (17%)	0 (0%)	-17

Table 2 shows that the largest increase in the proportion of students demonstrating full understanding occurred in Cycle 1, with an increase of 89 percentage points. In Cycle 2, the proportion increased by 39 percentage points, from 44% to 83%. Both cycles also showed a reduction in the proportion of students with insufficient understanding to 0% at the post-test. These patterns indicate that the distribution of students shifted toward higher mastery categories following the Fraction Tower Challenge activities in each cycle.

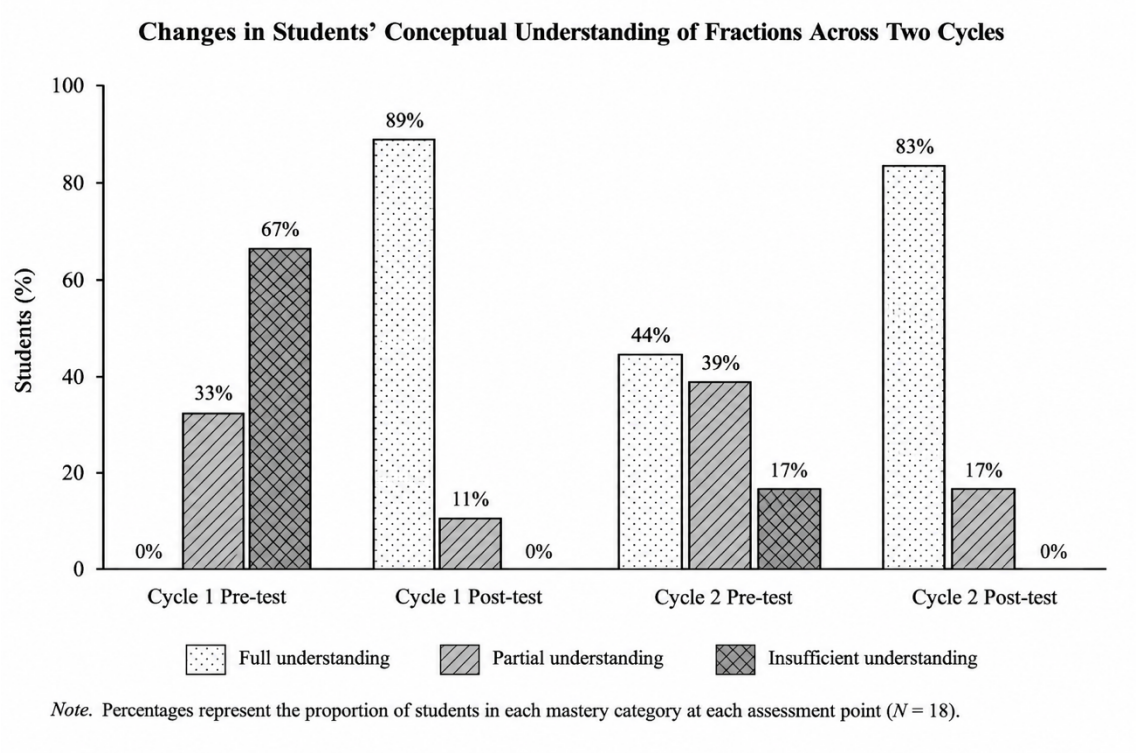


Figure 2. Pretest and Posttest

Overall, the classroom action research demonstrated substantial improvements in students' learning mastery across the two research cycles. During the first cycle, the implementation of the Fraction Tower Challenge resulted in noticeable gains in

conceptual understanding. The second cycle, conducted through individual learning activities, produced further improvements. Analysis of learning mastery indicated three categories of achievement: understanding, partial understanding, and lack of understanding. During the first-cycle pre-test, none of the students were categorized as demonstrating full understanding, while 33% demonstrated partial understanding and 67% showed insufficient understanding. Following the intervention, 89% of students achieved full understanding, whereas the remaining 11% demonstrated partial understanding. Reflection suggested that the remaining difficulties were associated with limited opportunities for individual participation, dominance of certain group members, and confusion regarding equivalent fractions.

In the second-cycle pre-test, 44% of students demonstrated full understanding, 39% showed partial understanding, and only 17% remained in the insufficient understanding category. Following the second-cycle intervention, 83% of students achieved full understanding, 17% demonstrated partial understanding, and none remained in the insufficient understanding category. The comparison between the two research cycles indicates a consistent improvement in students' learning mastery. Most importantly, the complete elimination of the insufficient understanding category in the second cycle provides strong evidence that the implementation of the Fraction Tower Challenge had a positive and meaningful impact on improving elementary school students' conceptual understanding of fractions.

DISCUSSION

Improvement in conceptual understanding

The main finding is that the proportion of students demonstrating full understanding of fractions increased markedly in both cycles, from 0% to 89% in Cycle 1 and from 44% to 83% in Cycle 2, and that no student remained in the insufficient category after either cycle. A plausible explanation is that the Fraction Tower Challenge allowed students to handle blocks proportional to different fractions, so that comparison and equivalence could be examined through visible and tangible relationships. Symbolic notation could then be connected to these relationships. This interpretation is consistent with the meta-analysis by Carbonneau et al. (2013), which reported small to moderate effects in favor of manipulatives over instruction with abstract symbols only, and moderate to large

effects on retention. It also aligns with the concreteness fading proposal of Fyfe et al. (2014), according to which concrete materials help learners interpret abstract symbols. Evidence from the game-based literature points in a similar direction. A systematic review by Hui and Mahmud (2023) reported positive impacts of game-based learning on cognitive and affective outcomes in mathematics, and Jarrah, Almassri, et al. (2022) reported a higher post-test mean for fifth graders who used a digital fraction game than for a control group.

The size of the improvement should be interpreted in relation to the study design. Average effects reported in meta-analyses are modest. Tokac et al. (2019) described a small positive effect of game-based learning on mathematics achievement, and the averages reported by Wouters et al. (2013) and Clark et al. (2016) were 0.29 and 0.33, respectively. Different magnitudes have been reported across studies, and the large proportional change observed here may be associated with differences in outcome measures, the very low baseline in Cycle 1, the small sample, and the absence of a comparison group. Because this study used no inferential test and no control condition, the changes cannot be separated from maturation, repeated testing, or other instructional influences. The findings suggest that the Fraction Tower Challenge is a promising supplement to fraction instruction in third grade, and they need testing in designs that include comparison groups.

Differences between cycles and retention

The gain in Cycle 2 was smaller than in Cycle 1, and the proportion of students showing full understanding at the Cycle 2 pre-test (44%) was lower than at the Cycle 1 post-test (89%). One explanation is that students started Cycle 2 from a higher baseline than in Cycle 1, which left less room for gain. The decline between the Cycle 1 post-test and the Cycle 2 pre-test is consistent with the reflection notes that some students forgot previously learned fraction concepts. Different retention patterns have been reported in the literature. Carbonneau et al. (2013) found moderate to large effects of manipulatives on retention, and Wouters et al. (2013) found higher learning when multiple sessions were involved. The pattern observed here may be associated with differences in the time between assessments, the number of exposures to the game, and the format of the tests, and retention was not examined systematically in this study. The Cycle 2 results therefore show that most students regained full understanding after an apparent loss of earlier gains,

and they should not be read as continued progress beyond Cycle 1. A practical implication is that teachers may plan short and periodic revisits to fraction concepts with the blocks after the initial unit.

Collaborative and individual activity

The shift from collaborative to individual activity is a second point of interpretation. In Cycle 1, the remaining difficulties were associated in the reflection with limited opportunities for individual participation, dominance of certain group members, and confusion about equivalent fractions. In Cycle 2, individual activity gave each student direct experience with the blocks and with their own errors, and 83% of students reached full understanding. Previous research offers context for this pattern. Wouters et al. (2013) found that learning with serious games was higher when players worked in groups. Kyndt et al. (2013) reported positive effects of cooperative learning that varied with study domain, age level, and culture. According to Gupta (2008), peer collaboration is useful in elementary mathematics and complements individual problem solving. The Cycle 2 results should be interpreted in relation to these findings. The change in grouping occurred together with other changes, including greater teacher attention, more encouragement, and differentiated support, so the effect of grouping cannot be isolated. The pattern is compatible with the view that group work and individual work serve different functions, with group work supporting exploration and discussion and individual work supporting consolidation. This view is a hypothesis for future testing, in line with the call of Hussein et al. (2022) for further research on how collaborative and competitive dynamics influence learning. For classroom practice, teachers may sequence group exploration with individual consolidation and assign roles in groups so that all students handle the blocks.

Conceptual difficulties and magnitude understanding

Students initially had difficulty identifying fractions, finding common denominators, and interpreting visual and numerical representations, and difficulties with comparing non-equivalent fractions persisted after Cycle 1. These difficulties resemble patterns reported in earlier studies. Gabriel et al. (2013) found that pupils applied procedures they did not fully understand, and Siegler et al. (2011) documented ways in which whole number understanding can distort understanding of fractions. Wijaya (2017) reported low conceptual understanding of fractions among Indonesian fourth graders, and Jarrah,

Wardat, et al. (2022) reported misconceptions in fraction addition and subtraction among seventh graders. A possible explanation for the improvement observed here is that tower height made fraction size visible, which may have supported comparison. Evidence by Siegler and Pyke (2013) and by Torbeyns et al. (2015) shows that fraction magnitude understanding relates to mathematics achievement. Magnitude understanding was not measured directly in this study, so this explanation remains an interpretation. Future versions of the game may be paired with magnitude tasks such as number line placement, and with a planned transition from blocks to symbols, as suggested by Fyfe et al. (2014).

Engagement

Observation notes recorded active discussion, comparison of fraction sizes, and teamwork during the game, and the reflection after Cycle 1 recorded off-task conversation, complaints about assignments, and perceptions of mathematics as uninteresting among some students. Hui and Mahmud (2023) reported positive impacts of game-based learning on motivation, interest, and engagement in their review, and Dowker et al. (2016) reviewed evidence on the relationship between mathematics anxiety and mathematics performance. The engagement observations in this study were qualitative and no instrument measured motivation or anxiety. The findings therefore offer descriptive indications of engagement, and future studies may add validated measures of motivation and mathematics anxiety.

Limitations and implications

Several limitations apply. The study involved 18 students in one classroom, used no comparison group, relied on descriptive analysis, and did not include a delayed post-test. The grouping structure changed together with other revisions between cycles. The findings should be interpreted as context-specific. For teachers, the Fraction Tower Challenge can be used as a concrete and visual supplement that links block-based comparison to symbolic fractions. For researchers, future studies may compare collaborative and individual versions of the game within controlled designs, include delayed post-tests to examine retention, and use inferential statistics with larger samples.

CONCLUSION

This Classroom Action Research aimed to improve third-grade students' conceptual understanding of fractions through the Fraction Tower Challenge. In Cycle 1, with

collaborative groups, the proportion of students showing full understanding rose from 0% to 89%. In Cycle 2, with individual activity, it rose from 44% to 83%, and no student remained in the insufficient understanding category after either cycle. The gain in Cycle 2 was smaller than in Cycle 1, and the lower proportion at the Cycle 2 pre-test suggests that some earlier gains were not retained between cycles. These findings indicate that the game was associated with improved conceptual understanding in this classroom, and they support its use as a concrete supplement to fraction instruction. Because the study involved a small sample and no comparison group, the findings should be confirmed in controlled studies with delayed post-tests and larger samples.

REFERENCES

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology, 105*(2), 380–400. https://doi.org/10.1037/a0031084

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122. https://doi.org/10.3102/0034654315582065

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: What have we learned in 60 years? *Frontiers in Psychology, 7*, Article 508. https://doi.org/10.3389/fpsyg.2016.00508

Fyfe, E. R., McNeil, N. M., Son, J. Y., & Goldstone, R. L. (2014). Concreteness fading in mathematics and science instruction: A systematic review. *Educational Psychology Review, 26*(1), 9–25. https://doi.org/10.1007/s10648-014-9249-3

Gabriel, F., Coché, F., Szucs, D., Carette, V., Rey, B., & Content, A. (2013). A componential view of children's difficulties in learning fractions. *Frontiers in Psychology, 4*, Article 715. https://doi.org/10.3389/fpsyg.2013.00715

Gupta, A. (2008). Constructivism and peer collaboration in elementary mathematics education: The connection to epistemology. *Eurasia Journal of Mathematics, Science and Technology Education, 4*(4), 381–386. https://doi.org/10.12973/ejmste/75364

Hui, H. B., & Mahmud, M. S. (2023). Influence of game-based learning in mathematics education on the students' cognitive and affective domain: A systematic review. *Frontiers in Psychology, 14*, Article 1105806. https://doi.org/10.3389/fpsyg.2023.1105806

Hussein, M. H., Ow, S. H., Elaish, M. M., & Jensen, E. O. (2022). Digital game-based learning in K-12 mathematics education: A systematic literature review. *Education and Information Technologies, 27*(2), 2859–2891. https://doi.org/10.1007/s10639-021-10721-x

Jarrah, A. M., Almassri, H., Johnson, J. D., & Wardat, Y. (2022). Assessing the impact of digital games-based learning on students' performance in learning fractions using (ABACUS) software application. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(10), Article em2159. https://doi.org/10.29333/ejmste/12421

Jarrah, A. M., Wardat, Y., & Gningue, S. (2022). Misconception on addition and subtraction of fractions in seventh-grade middle school students. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(6), Article em2115. https://doi.org/10.29333/ejmste/12070

Kyndt, E., Raes, E., Lismont, B., Timmers, F., Cascallar, E., & Dochy, F. (2013). A meta-analysis of the effects of face-to-face cooperative learning: Do recent studies falsify or verify earlier findings? *Educational Research Review, 10*, 133–149. https://doi.org/10.1016/j.edurev.2013.02.002

Manfra, M. M. (2019). Action research and systematic, intentional change in teaching practice. *Review of Research in Education, 43*(1), 163–196. https://doi.org/10.3102/0091732X18821132

Ninaus, M., Kiili, K., McMullen, J., & Moeller, K. (2017). Assessing fraction knowledge by a digital game. *Computers in Human Behavior, 70*, 197–206. https://doi.org/10.1016/j.chb.2017.01.004

Siegler, R. S., Duncan, G. J., Davis-Kean, P. E., Duckworth, K., Claessens, A., Engel, M., Susperreguy, M. I., & Chen, M. (2012). Early predictors of high school mathematics achievement. *Psychological Science, 23*(7), 691–697. https://doi.org/10.1177/0956797612440101

Siegler, R. S., & Pyke, A. A. (2013). Developmental and individual differences in understanding of fractions. *Developmental Psychology, 49*(10), 1994–2004. https://doi.org/10.1037/a0031200

Siegler, R. S., Thompson, C. A., & Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Psychology, 62*(4), 273–296. https://doi.org/10.1016/j.cogpsych.2011.03.001

Tokac, U., Novak, E., & Thompson, C. G. (2019). Effects of game-based learning on students' mathematics achievement: A meta-analysis. *Journal of Computer Assisted Learning, 35*(3), 407–420. https://doi.org/10.1111/jcal.12347

Torbeyns, J., Schneider, M., Xin, Z., & Siegler, R. S. (2015). Bridging the gap: Fraction understanding is central to mathematics achievement in students from three different continents. *Learning and Instruction, 37*, 5–13. https://doi.org/10.1016/j.learninstruc.2014.03.002

Wang, L.-H., Chen, B., Hwang, G.-J., Guan, J.-Q., & Wang, Y.-Q. (2022). Effects of digital game-based STEM education on students' learning achievement: A meta-analysis. *International Journal of STEM Education, 9*(1), 1–13. https://doi.org/10.1186/s40594-022-00344-0

Wijaya, A. (2017). The relationships between Indonesian fourth graders' difficulties in fractions and the opportunity to learn fractions: A snapshot of TIMSS results. *International Journal of Instruction, 10*(4), 221–236. https://doi.org/10.12973/iji.2017.10413a

Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology, 105*(2), 249–265. https://doi.org/10.1037/a0031311