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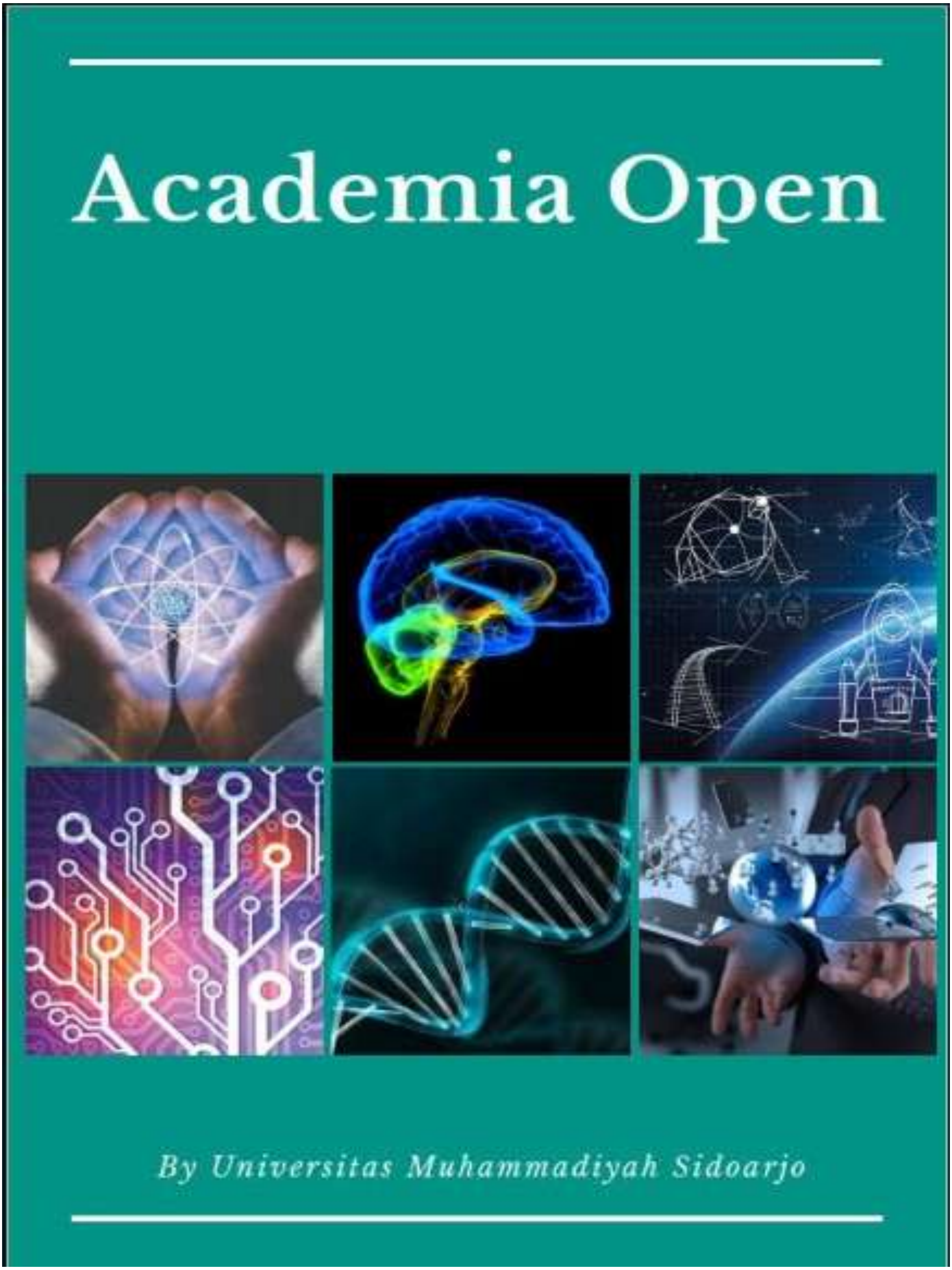

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Manipulative Learning Accommodates Fraction Comprehension In Inclusive Elementary Classrooms: Pembelajaran Manipulatif Mengakomodasi Pemahaman Pecahan Di Ruang Kelas Dasar Inklusif

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Abstract

General Background Mathematics education requires logicalreasoning, where fractions representa notoriously difficult transition from whole-number concepts to proportional thinking. **Specific Background** Within inclusive elementary environments, traditional teacher-centered instruction frequently fails to provide concrete learning experiences, leaving regular learners alongside students with dyscalculia or slow learning traits struggling to interpret abstract numerical representations. **Knowledge Gap** Although physical learning tools are widely researched in homogeneous settings, empirical evidence detailing their systematic application to simultaneously support neurotypical children and those with special educational needs in a single space remains scarce. **Aims** This Classroom Action Research investigates the application of concrete instructional materials, guided by Bruner's cognitive representation stages, to advance mathematical understanding among twenty-three diverse fourth-grade students at SD Negeri 017 Sangatta Utara. **Results** The intervention significantly raised classical conceptual mastery from a 26.09% pre-action baseline to 86.96% by the conclusion of the second cycle. Furthermore, the students' average test scores increased substantially from 55.21 to 77.26. **Novelty** This study uniquely validates that transitioning sequentially through enactive, iconic, and symbolic representations using tangible objects successfully bridges the cognitive demands of abstract mathematics for highly diverse learner profiles simultaneously. **Implications** Educators must adopt hands-on pedagogical strategies to provide equitable, concrete learningscaffoldsthataccommodateindividualizedcognitiverequirementsduringcomplexarithmetic instruction.

Highlights

- Utilizing concrete instructional materials successfully bridges abstract mathematical gaps for slow learners and dyscalculic students.
- Conceptual mastery of proportional mathematics surged from a 26.09% baseline to an 86.96% final achievement rate.
- Transitioning sequentially through distinct cognitive stages minimizes cognitive overload during complex arithmetic instruction.

Keywords

Inclusive Education; Manipulative Instruction; Fraction Comprehension; Cognitive Representation; Classroom Action Research

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INTRODUCTION

Mathematics education is a key tool for the development of students' logical, systematic and analytical thinking skills, which are indispensable skills for learning and solving problems throughout life. Of elementary mathematics topics, fractions are consistently identified as one of the most difficult concepts since they demand that students transition from whole-number thinking to understanding part-whole relationships, proportional thinking, and symbolic representations. Students should build conceptual understanding enabling them to make sense of fractions and use them in real settings rather than just memorizing computational rules. But this remains a constant challenge in many educational settings. The challenge of learning fractions can be seen in both international and national assessments. Based on the Programme for International Student Assessment (PISA) 2022, Indonesian students still show a relatively low level of mathematical literacy, with an average mathematics score of 366, ranking low among participating countries, indicating significant difficulties in mathematical reasoning and conceptual understanding (OECD, 2023). The findings indicate that many students still have difficulty in relating mathematical symbols to conceptual meanings, particularly in learning abstract topics such as fractions.

The challenge is even greater in the context of inclusive classrooms, where students with different learning characteristics learn together in the same instructional environment. Inclusive education seeks to provide equal learning opportunities by meeting the differences in students' abilities, learning speed and educational needs. However, mathematics instruction in many inclusive elementary classrooms remains heavily based on traditional teacher-centered approaches that emphasize verbal explanations and symbolic procedures. Often such instructional practices do not provide enough concrete learning experiences for students who are experiencing learning difficulties, and therefore they have a superficial understanding and low learning achievement. This condition was found in grade IV SD Negeri 017 Sangatta Utara. There were 23 students in the classroom, one of them was a slow learner student and two other students showed characteristics of dyscalculia. Analysis of the results of the Mid-Semester Assessment (PTS) on the subject of fractions shows that only six students (26.09%) achieved the Minimum Mastery Criterion (KKM) of 65 school. Moreover, classroom observations showed students faced difficulties comparing fractions with both similar and different denominators, understanding fractions as parts of a whole, and interpreting visual representations into mathematical symbols. Conceptual weaknesses lead students to have less confidence and motivation to learn mathematics. Students with slow learning characteristics generally needed more time for instruction and repeated explanations, while students with dyscalculia had continuous difficulties in understanding numerical relationships, quantity representations, and basic arithmetic concepts (Septiana et al., 2024). Hence, the diversity of learning needs in an inclusive classroom calls for instructional strategies that are concrete, flexible and sensitive to individual differences.

Previous studies have consistently demonstrated the educational advantages of manipulatives in mathematics learning. A meta-analysis by Carbonneau et al. (2013) reported that manipulatives have a significant impact on mathematics achievement, especially when used with explicit instructional guidance and not as a stand-alone teaching tool. Anjani et al. (2021) in this regard found that physical manipulatives such as fraction circles, fraction blocks and folding paper help elementary students to understand the concept of fractions by making abstract mathematical ideas into tangible learning experiences. These encouraging and promising findings notwithstanding, most of the research so far has been conducted in regular classrooms with relatively homogeneous student populations. There is a dearth of empirical research on the systematic implementation of manipulative-based learning in inclusive elementary classrooms, particularly for enhancing fraction conceptual understanding among students with diverse learning needs. The gap points to the need for more research on instructional practices that can support regular students and students with learning difficulties simultaneously. The effectiveness of manipulative learning is strongly supported by well-established educational theories. Bruner's (1996) Theory of Cognitive Development suggests that meaningful learning develops through three modes of representation: enactive, iconic, and symbolic. Students first construct knowledge by physically manipulating concrete objects , then by using visual representations , and finally by understanding abstract mathematical symbols . Manipulative learning exposes students to these developmental stages in a systematic way, thereby reducing cognitive overload as they transition from concrete experiences to symbolic reasoning. Furthermore, Vygotsky's idea of the Zone of Proximal Development (ZPD) emphasizes that students reach greater levels of understanding when provided with suitable scaffolding that is customized to their personal learning requirements (Vygotsky, 1978). Manipulative materials are instructional scaffolds that in inclusive classrooms enable teachers to differentiate instruction and keep all learners actively involved.

Based on the theoretical and empirical considerations, manipulative-based learning is proposed in this study as an instructional intervention in teaching fractions in an inclusive elementary classroom. Students investigate, compare, build and represent fractions using concrete learning materials such as fraction circles, fraction strips and folding paper activities to provide meaningful, hands-on experiences before moving to the abstract mathematical notation. Manipulative learning offers fun and interesting classroom activities that promote active participation and at the same time improve the understanding of concepts (Raharap, 2023). These learning experiences are particularly important in inclusive settings because they cater to the needs of a variety of cognitive characteristics and learning styles, and encourage collaborative participation of students. Therefore, this classroom action research is intended to find out whether the implementation of manipulative-based learning can improve the conceptual understanding of fractions of the fourth-grade students in an inclusive classroom at SD Negeri 017 Sangatta Utara. The study discusses the function of manipulative learning in developing conceptual thinking through concrete experiences and the different educational needs of normal students, slow learners and students with dyscalculia. The results are expected to provide useful evidence on adaptive mathematics instruction and an effective model of instruction for inclusive elementary education.

METHOD

The study used the Classroom Action Research (CAR) based on the model of Kemmis and McTaggart which has four cyclical stages, namely planning, action, observation and reflection. This research was conducted in two action cycles in SD Negeri

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017 Sangatta Utara, East Kutai Regency, Indonesia in the 2025/2026 school year. All the study participants were 23 fourth grade students in the inclusive classroom, 20 regular students, one slow learner and two students with characteristics of dyscalculia. The choice of the research site was motivated by the fact that inclusive education was being implemented there and there was a need to improve students' conceptual understanding of fractions using more adaptive instructional strategies. The intervention was manipulative based learning based on Bruner's stages of cognitive representation (enactive, iconic and symbolic). First, students investigated fraction concepts with hands-on activities using concrete manipulatives such as fraction circles, fraction games, and folding paper. They then visualized these experiences , and later on transcribed them into mathematical symbols . The learning activities were performed collaboratively in heterogeneous groups in order to provide differentiated support and scaffolding to students with different learning characteristics during the learning process. The reflection from the first cycle was used to improve the instructional procedures and learning materials that were implemented in the second cycle.

Data were collected by means of classroom observation, tests of conceptual understanding, field notes, and documentation. The learning engagement, manipulation of instructional materials, participation in group discussion, conceptual explanation, symbolic representation and problem solving performance of the students were assessed using observation sheets. Conceptual understanding tests were administered at the end of each learning cycle to assess students' understanding of fraction concepts. During the intervention, documentation such as photographs, students' worksheets and field notes were used to substantiate and validate observational findings. Quantitative data from the conceptual understanding tests were analyzed descriptively by comparing the mean scores and the percentage of classical learning mastery of students in the pre-action stage, Cycle I, and Cycle II. Mastery of learning was said to be achieved by students if they attained a score of at least 65, and classroom intervention was said to be successful if at least 80% of students met the mastery criteria. Qualitative data were collected through observations, field notes, and documentation and analyzed through data reduction, categorization, interpretation, and reflection to determine changes in students' learning behaviors and the effectiveness of manipulative-based instruction in the inclusive classroom.

RESULT AND DISCUSSION

Initial Condition (Pre-Cycle)

The mathematics instruction of the inclusive fourth grade of SD Negeri 017 Sangatta Utara before the implementation of the classroom action was dominated by the teacher by using conventional methods and with minimum instructional media. Mostly learning activities were based on verbal explanations and textbook exercises. The students had difficulties to understand the abstract concept of fractions. The lack of concrete learning media limited students' opportunities to develop meaningful conceptual understanding, especially in relating visual representations of fractions to mathematical symbols. An initial diagnostic assessment was administered on May 18, 2026, to determine students' prior knowledge of fraction concepts before the intervention. The assessment consisted of five descriptive questions on basic fraction concepts including comparing, ordering, interpreting and representing fractions. Classroom observations during the pre-cycle stage revealed that most of the students encountered great difficulties in comparing and ordering fractions and interpreting fractions representations. These challenges were more pronounced for students with diverse learning needs, including a slow learner and two students with characteristics of dyscalculia, who required more concrete learning experiences and supplemental instructional support.

Results of the pre-cycle assessment revealed that the students' conceptual understanding of fractions was generally low. Of the 23 students who participated, six students attained the Minimum Competency Score (KKM) of 65, and the remaining seventeen students did not achieve the expected level of achievement. The class average score was 55.21 and the classical learning mastery was only 26.09%, which indicated that almost three-fourths of the students had not yet mastered the targeted competencies. These findings supported the fact that students' knowledge of the concept of fractions was still lacking and highlighted the need for instructional improvement. Based on these initial findings, manipulative-based learning was chosen as the instructional intervention in this classroom action research. It was hoped that concrete manipulatives would translate abstract mathematical concepts into concrete learning experiences in which students actively construct conceptual understanding through exploration, discussion and interaction with concrete manipulatives. This approach was seen as especially suitable for the inclusive classroom as it could accommodate students with diverse cognitive characteristics and also promote more engagement and meaningful learning.

Cycle I

The theme of the first meeting of Cycle I was implementing manipulative-based learning to improve students' conceptual understanding of fractions which was conducted on May 18, 2026. Before the lesson, the researcher prepared lesson plan, observation sheets, conceptual understanding tests and manipulative learning materials such as origami paper, ruler, scissors and markers. Learning activities began with an introduction of learning objectives and then teacher demonstrations with concrete manipulatives to show fraction concepts. The students were then divided into mixed groups and asked to complete worksheet activities. This was done by manipulating the learning materials, discussing what they found and presenting the results of their group work. The teacher guided and supported more during the lesson especially to those students who had challenges in the use of the manipulatives or the understanding of the concepts. Classroom observations revealed that manipulative-based learning implementation was not yet optimal. The lesson illustrated several instructional difficulties. The teacher had not always given clear and sequential instructions . Classroom management was not as effective and the lesson ended without a comprehensive summary of the learning outcomes. From the students' perspective, a number of learners had difficulty manipulating the manipulatives and continued to rely on the concrete representations without successfully transferring their understanding to symbolic fraction notation. Moreover, in the classroom the more active students tended to dominate the discussion while the less active students and those with special educational needs were less active. Some students also were resistant to working on the individual exercises given at the end of the lesson.

The evaluation after the first meeting showed that the students' conceptual understanding of fractions was still relatively low, but there was an initial improvement compared to the pre-cycle condition. Of the 23 students who took part in the study, seven students have been able to achieve the Minimum Mastery Criterion (KKM) while sixteen students have not reached the expected mastery. The percentage of classical learning mastery increased to 30.43%. The percentage of students below the established criterion was 69.57%. The results showed that the first use of manipulative-based learning had begun to have a positive effect but more instructional improvements were still necessary for students' conceptual understanding at the follow-up meeting.

Table 1. *Students' Conceptual Understanding and Learning Activity in Cycle I*

Indicator	Meeting 1	Meeting 2
Students achieving conceptual mastery, *n* (%)	7 (30.43%)	10 (43.48%)
Students not achieving conceptual mastery, *n* (%)	16 (69.57%)	13 (56.52%)
Learning activities implemented, *n* (%)	12 (52.17%)	15 (65.22%)
Learning activities not implemented, *n* (%)	11 (47.83%)	8 (34.78%)

The results in Table 1 show a gradual improvement in students' conceptual understanding of fractions and the implementation of learning activities in Cycle I. In Meeting 1, 30.43% of students (7 of 23 students) achieved the Minimum Mastery Criterion, and in Meeting 2, 43.48% of students (10 of 23 students) achieved the Minimum Mastery Criterion. Likewise, the planned learning activities implementation improved from 52.17% to 65.22% which suggests that the instructional process was more organized after the revisions made after the first meeting. Nevertheless, these improvements are significant, but the learning outcomes have not yet achieved the defined success criteria. By the end of Cycle I, more than half of the students (56.52%) failed to reach conceptual mastery. Classroom observations indicated that some students were passive during group discussions, overly dependent on teacher directions when using the manipulatives, and had difficulty linking concrete representations to symbolic fraction notation. Special education needs (SEN) students, especially the slow learners and students with mathematics learning difficulties, needed more intensive scaffolding in order to understand the fraction comparison and ordering tasks.

Findings from Cycle I were used to inform instruction in the next cycle. The planned improvements included more individualized scaffolding, more opportunities for all students to participate in group discussions, better connections between concrete manipulatives, visual representations, and symbolic fractions using gradual learning activities, better organization of heterogeneous groups, and varied contextual practice with immediate feedback. It was expected that these refinements would improve students' conceptual understanding and the overall effectiveness of manipulative-based learning in Cycle II.

Cycle II

Reflection from Cycle I brought about several instructional improvements in Cycle II to cope with the difficulties encountered during the previous cycle. The teacher provided more systematic scaffolding, more explicit step-by-step instructions on how to use the manipulatives, more intensive individualized support for students with special educational needs and better organization of heterogeneous group discussions. Students also had more chances to relate concrete manipulative activities to visual and symbolic representations of fractions through repeated practice and guided discussion. The changes were made to enhance conceptual understanding and increase student participation in the learning process. These improvements were implemented and resulted in notable improvements to students' conceptual understanding and classroom learning activities. At the first meeting of Cycle II, 18 of 23 students (78.26%) met the Minimum Mastery Criterion (KKM). The implementation of learning activities was 82.61%. Although some students were less active in the group discussions, and the teacher's assistance was still focused on a few students with learning difficulties, the overall learning process was more structured and more effective than in Cycle I. At the second meeting, even more improvements were noted. The number of students who reached mastery increased to 20 (86.96%), while only 3 students (13.04%) are below the mastery criterion. Additionally, all planned learning activities were successfully implemented (100%). This indicates that the instructional procedures were implemented consistently and effectively throughout the lesson. The findings indicate that the repeated use of manipulative-based learning, along with systematic scaffolding and collaborative learning, led to significant improvement in students' conceptual understanding of fractions in the inclusive classroom.

Table 2. *Students' Conceptual Understanding and Learning Activity in Cycle II*

Indicator	Meeting 1	Meeting 2
Students achieving conceptual mastery, *n* (%)	18 (78.26%)	20 (86.96%)
Students not achieving conceptual mastery, *n* (%)	5 (21.74%)	3 (13.04%)
Learning activities implemented, *n* (%)	19 (82.61%)	23 (100.00%)
Learning activities not implemented, *n* (%)	4 (17.39%)	0 (0.00%)

The results in Table 2 show a significant increase in students' conceptual understanding of fractions and the implementation of learning activities in Cycle II. The percentage of students who met the Minimum Mastery Criterion rose from 78.26% (18 out of 23 students) in Meeting 1 to 86.96% (20 out of 23 students) in Meeting 2. Simultaneously, the execution of planned learning activities improved from 82.61% to 100%, indicating that all instructional procedures were successfully implemented during the second meeting. Such results suggest that the instructional revisions implemented after Cycle I had a positive effect on both the quality of classroom instruction and students' conceptual learning outcomes. Some students still needed intensive guidance in the first meeting of Cycle II, especially students with special educational needs. However, classroom participation was more balanced than Cycle I. Students were more confident to manipulate the fraction learning

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materials, participated more actively in group discussions, and demonstrated a better ability to relate concrete manipulative experiences with visual and symbolic representations of fractions . The increased familiarity with the learning media also reduced students' dependence on teacher assistance, so that collaborative learning activities could proceed more effectively. By the end of Cycle II, the pre-determined criterion for classroom success had been met. Only 13.04% (3 students) were still under the Minimum Mastery Criterion. All planned learning activities were successfully implemented. These findings demonstrate that repeated exposure to manipulative-based learning, coupled with systematic scaffolding and continuous instructional refinement, significantly improved students' conceptual understanding of fractions in the inclusive classroom. The improvement of the two meetings shows the effectiveness of the intervention in facilitating the active participation in learning and mastery of concepts.

Table 3. *Average Scores of Students' Conceptual Understanding Across the Research Cycles*

Cycle	Meeting	Average Score
Cycle I	Meeting 1	59.00
Cycle I	Meeting 2	63.00
Cycle II	Meeting 1	74.30
Cycle II	Meeting 2	77.26

Table 3 shows the average scores indicating the improvement of students' conceptual understanding of fractions in the two cycles of the research. In the first Cycle I, the average value of the class rose from 59.00 in the 1st meeting to 63.00 in the 2nd meeting. This shows an increase in the initial stage after the application of manipulative-based learning. But the average score is still below the set Minimum Mastery Criterion (KKM) of 65, which means there is a need to improve the teaching. In Cycle II, some changes of instruction were introduced based on reflection of Cycle I and a more substantial progress was noticed. The average of the class went up to 74.30 in Meeting 1 and then went up again to 77.26 in Meeting 2. The continued growth is indicative of the repeated use of manipulative learning activities and more systematic scaffolding and individualized support that helped students construct a more robust conceptual understanding of fractions. The class average was higher than the mastery criterion at the end of Cycle II, indicating that the intervention was effective in improving students' conceptual understanding in the inclusive classroom.

Table 4. *Students' Conceptual Mastery Across the Research Cycles*

Cycle	Meeting	Students Achieving Mastery, n (%)	Students Not Achieving Mastery, n (%)
Cycle I	Meeting 1	7 (30.43%)	16 (69.57%)
Cycle I	Meeting 2	10 (43.48%)	13 (56.52%)
Cycle II	Meeting 1	18 (78.26%)	5 (21.74%)
Cycle II	Meeting 2	20 (86.96%)	3 (13.04%)

The results in Table 4 show that students' conceptual understanding of fractions significantly improved during the intervention. Cycle I: 30.43% (7 of 23 students) of students met the Minimum Mastery Criterion in Meeting 1, and 43.48% (10 of 23 students) met the Minimum Mastery Criterion in Meeting 2. However, this was gradual progress, and over half of the students remained below the mastery criterion; thus, the instructional objectives had not yet been fully realized. A larger decrement was observed in Cycle II following the instructional revisions following the reflection phase. The number of students who have achieved mastery increased to 18 (78.26%) in Meeting 1 and 20 students (86.96%) in Meeting 2, while the percentage of students who have not yet achieved mastery decreased from 21.74% to 13.04%. These results suggest that the instructional changes made in Cycle II were effective in improving students' conceptual understanding of fractions. In general, the trend over the four meetings is one of a steady increase in the number of students reaching conceptual mastery and a decrease in the number who did not reach the Minimum Mastery Criterion. The achievement of classical mastery of 86.96% on the final meeting has exceeded the predetermined success criterion which is 80%. This shows that learning based on manipulative can improve students' conceptual understanding of fractions in the inclusive classroom.

Discussion

The results of this study suggest that manipulative-based learning was effective in improving fourth grade students' conceptual understanding of fractions in an inclusive classroom. The improvement can be seen from the average achievement scores and the percentage of students who pass the Minimum Mastery Criterion (KKM). The class average increased gradually from 59.00 in the first meeting of Cycle I to 77.26 in the second meeting of Cycle II and classical mastery increased from 30.43% to 86.96%. These results were above the a priori criterion for success of 80% suggesting that the intervention was effective in improving students' understanding of fractions concept. The continuous improvement across these two action research cycles also suggests that the repeated exposure to the manipulative learning activities as well as the instructional refinement after each stage of reflection contributed to better learning outcomes. The improvement of students' conceptual understanding was due to the use of concrete manipulatives which allowed students to develop mathematical meaning through concrete experience before moving on to visual and symbolic representations. The intervention included students using the fraction games and origami materials to physically compare, order and represent fractions, making abstract mathematical ideas more accessible. This process of learning is consistent with Bruner's theory of representation that suggests the gradual development of conceptual understanding through enactive, iconic and symbolic stages. Allowing students to physically interact with the learning materials before solving symbolic problems helped the students to make better conceptual connections and reduce common misconceptions with fractions.

Instructional improvements conducted after the reflection stage of Cycle I also played another important role in improving the learning outcomes. In Cycle II, the teacher provided more structured scaffolding, clearer step-by-step instructions, more personalized help to students with special educational needs and a better organization of heterogenous group discussions. These changes made a more supportive learning environment and students became more confident in their use of the manipulatives and in their active participation in collaborative learning. This in turn led to greater class participation and conceptual understanding. This indicates that successful manipulative-based learning depends not only on the availability of instructional material but also on the appropriate guidance provided by the teacher and structured learning activities. The findings are particularly relevant in the context of inclusive education. Students with mathematics learning difficulties and slow learners were provided repeated opportunities to experience the mathematical concepts through concrete representations. The manipulatives helped to reduce the cognitive demands of the abstract notation of fractions by providing visual and kinesthetic experiences for the conceptual construction. Individualized scaffolding and peer collaboration further supported students' ability to connect concrete experiences with symbolic representations to facilitate more meaningful participation in classroom learning.

These results are consistent with previous studies reporting that manipulative-based instruction improves understanding of mathematical concepts, especially in elementary education. Research has indicated that concrete learning materials help students to visualize mathematical relationships, promote active engagement, and improve conceptual reasoning before the introduction of procedural learning. The present study contributes to this evidence by demonstrating that manipulative-based learning can also be effectively implemented in an inclusive classroom, with students of diverse cognitive characteristics and learning needs. The results suggest that manipulative-based learning is an effective instructional strategy for the teaching of fractions and an inclusive pedagogical approach that encourages equitable participation and conceptual learning for all students.

CONCLUSION

The result of this classroom action research shows that the manipulative-based learning is effective to improve the conceptual understanding of fractions of fourth grade students in inclusive classroom in SD Negeri 017 Sangatta Utara. The intervention has produced a consistent improvement in both research cycles, evidenced by the increase in the class average score from 55.21 in the pre-cycle to 77.26 at the end of Cycle II and the increase in classical mastery from 26.09% to 86.96%, exceeding the success criterion of 80%. These findings demonstrate that learning based on manipulation, assisted by systematic support and collaborative learning activities, helps students move from concrete experiences to symbolic representations and enhances the conceptual understanding of fractions among both regular students and students with special educational needs. The results of this study suggest that teachers should adopt manipulative based learning continuously in teaching abstract mathematical concepts especially fractions with structured scaffolding and differentiated support based on students' learning needs. Schools should facilitate this by providing adequate instructional resources and motivating teachers to create innovative, low-cost manipulative learning materials for inclusive learning. Future work is suggested to investigate the effectiveness of manipulative-based learning with larger samples, different mathematical topics and different educational settings to enhance the generalizability of the findings.

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