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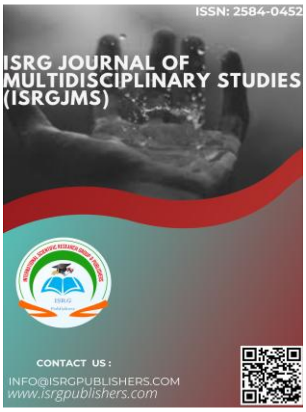

Hypothetical Learning Trajectory (HLT) For Fraction Concepts Based on The Ethnomathematics of Mamasa Traditional Carving (Sura' Doti Wai) in Elementary School

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Abstract

This study was motivated by elementary school students' difficulties in understanding the abstract concept of fractions, which is often taught without sufficient connection to students' real-life experiences and local cultural contexts. This study aims to develop a Hypothetical Learning Trajectory (HLT) for learning fractions through an ethnomathematical approach using the Mamasa traditional carving Sura' Doti Wai as a learning context. This study employed a design research approach based on the model developed by Gravemeijer and Cobb, consisting of three main stages: preliminary design, teaching experiment, and retrospective analysis. The participants were fifth-grade students at SDN 020 Saloan, Mamasa Regency, Indonesia. Data were collected through direct observation, field notes, and documentation of students' work in Student Worksheets (LKPD). The implementation of the initial HLT in Cycle 1 revealed several learning obstacles, including difficulties in understanding formal mathematical terminology, misconceptions in determining fraction values, and difficulties in understanding the requirement that a whole must be divided into equal-sized parts. Based on these findings, the HLT was revised by simplifying the mathematical language, providing guided questions, and introducing concrete activities such as cutting, stacking, and comparing parts of the images. The implementation of the revised HLT in Cycle 2 showed that the learning obstacles were reduced and that students developed a more meaningful understanding of fractions. Students were able to identify basic geometric forms, determine parts of a whole, and understand that a fraction represents a whole divided into equal-sized parts. Therefore, the Mamasa traditional carving Sura' Doti Wai can serve as a meaningful ethnomathematical context for developing a concrete and contextual learning trajectory for fraction concepts in elementary school.

Keywords: *Design Research; Hypothetical Learning Trajectory; Fractions; Ethnomathematics; Sura' Doti Wai.*

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INTRODUCTION

Mathematics plays an important role in developing students' logical, analytical and systematic thinking skills. However, mathematics is often perceived by elementary school students as difficult and less interesting because many mathematical concepts are presented in abstract forms and are not sufficiently connected to students' everyday experiences. This condition is particularly evident in the learning of fractions. Fractions require students to understand the relationship between a part and a whole, the meaning of the numerator and denominator, and the principle that a whole must be divided into equal parts. These concepts can be challenging for elementary school students when they are introduced only through symbolic representations without providing meaningful and concrete experiences.

The difficulties experienced by students in learning fractions indicate the importance of providing learning contexts that are familiar and meaningful to them. Mathematics learning should not only focus on the mastery of formal mathematical procedures but also provide opportunities for students to construct mathematical concepts through real situations. The use of contextual learning can help students connect informal knowledge acquired from their environment with formal mathematical concepts. In this regard, local culture can provide a meaningful context for mathematics learning because it is closely related to students' daily lives and social environment.

One approach that can be used to connect mathematics with local culture is ethnomathematics. Ethnomathematics emphasizes the existence of mathematical ideas, concepts, and practices within cultural activities and traditions. Integrating ethnomathematics into mathematics learning provides opportunities for students to recognize mathematical concepts through cultural objects that are familiar to them. Such an approach can make abstract mathematical concepts more concrete while simultaneously strengthening students' appreciation of their local cultural heritage.

One of the cultural contexts that has the potential to be integrated into mathematics learning is the traditional Mamasa carving known as *Sura' Doti Wai*. This carving contains geometric patterns with regular and symmetrical arrangements. The pattern can be used to represent the concept of a whole divided into several parts. In particular, the circular pattern can be divided into four equal parts, providing a concrete representation of the fraction one-fourth (1/4). Through this context, students can observe the relationship between the whole and its parts before moving toward the formal symbolic representation of fractions.

The use of *Sura' Doti Wai* is also relevant because the carving contains cultural values related to order, balance, and fairness. These values can be connected to the fundamental principle of fractions, namely that a whole must be divided into equal-sized parts. Thus, students can understand that the concept of fairness in dividing a cultural object has a mathematical relationship with the requirement of equal partitioning in fractions. This connection provides an opportunity for mathematics learning to become not only conceptually meaningful but also culturally relevant.

Previous studies have shown that ethnomathematical contexts can support the development of meaningful mathematics learning trajectories. In addition, research on *Hypothetical Learning Trajectory* (HLT) has demonstrated that learning trajectories can be developed by predicting students' thinking, anticipating learning obstacles, and designing teacher interventions based on students' actual responses during the learning process. Therefore, HLT can serve as an appropriate framework for designing and refining mathematics learning through an ethnomathematical context.

In this study, the learning trajectory is developed through a *design research* approach. The initial HLT is designed based on an analysis of the learning objectives, students' characteristics, the concept of fractions and the mathematical potential of the *Sura' Doti Wai* carving. The initial design is then implemented in the classroom to identify students' actual responses and learning obstacles. The findings from the first cycle are used as a basis for revising the HLT, which is subsequently implemented in the second cycle. This iterative process allows the learning trajectory to be refined based on empirical evidence from the classroom.

The first implementation is expected to reveal the extent to which students can understand fractions through the visual representation of *Sura' Doti Wai*, as well as the obstacles that may arise during the learning process. The subsequent revision focuses on addressing these obstacles through simplified language, guided questions, and concrete activities that enable students to physically explore equal and unequal parts.

Based on this background, this study aims to develop and examine a *Hypothetical Learning Trajectory* for teaching fraction concepts through the ethnomathematical context of the Mamasa traditional carving *Sura' Doti Wai*. Specifically, this study investigates: (1) the initial learning trajectory for fraction concepts based on the *Sura' Doti Wai* carving; (2) the implementation of the initial HLT and the revisions made based on the identified learning obstacles; and (3) the implementation and effectiveness of the revised HLT in supporting students' understanding of fundamental fraction concepts.

RESULTS

The results of this study are presented chronologically according to the stages of the design research, namely the preliminary design, the first teaching experiment (Cycle 1), and the revised teaching experiment (Cycle 2). The findings focus on the development of the Hypothetical Learning Trajectory (HLT), students' learning obstacles, and changes in students' understanding of fractions through the ethnomathematical context of the Mamasa traditional carving *Sura' Doti Wai*.

1. Preliminary Design

The preliminary design began with an analysis of the Mathematics Learning Outcomes (Capaian Pembelajaran/CP) for Phase C and an identification of students' difficulties in learning fractions. The analysis indicated that students tended to perceive fractions as two separate numbers rather than as a representation of a part-to-whole relationship. In addition, students had not fully understood that a whole must be divided into equal-sized parts in order to represent a fraction appropriately.

To address these difficulties, the cultural context of *Sura' Doti Wai* was incorporated into the learning trajectory. The geometric characteristics of the carving provide a meaningful visual and concrete context for representing a whole and its equal partitions. In the learning design, one complete *Sura' Doti Wai* motif was represented as one whole (1), which was subsequently divided into four equal parts to introduce the concept of one-fourth (1/4).

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The initial HLT consisted of three learning activities. The first activity involved cultural orientation and identification of the whole object through observation of the *Sura' Doti Wai* motif. The second activity focused on constructing fraction notation by coloring parts of the carving pattern and relating the colored parts to the whole. The third activity focused on investigating the essential condition of a fraction, namely that a whole must be divided into equal parts, through comparisons of visual representations.

The HLT was subsequently developed into teaching materials and Student Worksheets (LKPD), including predicted student responses, anticipated learning obstacles, and possible teacher interventions.

2. Results of Cycle 1

2.1 Cultural Orientation and Identification of Geometric Shapes

At the beginning of Cycle 1, students were introduced to the *Sura' Doti Wai* carving through pictures and an explanation of its cultural meaning. The students showed considerable interest in the carving; however, their initial attention was directed mainly toward its aesthetic characteristics. They had not yet recognized the mathematical elements embedded in the pattern.

When students were asked to identify the geometric shape represented in the carving, difficulties emerged because of the formal mathematical terminology used in the LKPD. Terms such as *"plane figure"* and *"circular plane"* were unfamiliar to some students. As a result, students gave various responses, including "square," "rectangle," and "box."

Similar difficulties appeared when students were asked to identify the complete circular area before it was carved. Some students responded with inaccurate answers, such as 6 or 2, or used expressions that did not correspond to the intended mathematical concept. These responses suggested that unfamiliar mathematical vocabulary became an initial learning obstacle.

2.2 Exploration of the Fraction Concept

The second activity required students to color one part of the carving pattern and interpret the relationship between the numbers in the fraction representation.

The students' responses revealed a misconception concerning the relationship between the numerator and denominator. Rather than relating the colored part to the total number of equal parts, several students compared the colored part with the remaining uncolored parts. Consequently, incorrect fraction representations were produced.

Another obstacle was related to the structure of the questions. The open-ended instructions were relatively long, and several students appeared reluctant to read and process the entire statement. This affected their ability to identify the relevant mathematical information needed to determine the fraction.

2.3 Understanding Equal Partitioning

The third activity was intended to develop students' understanding that the parts of a fraction must be equal in size. Students were presented with Figure A, which represented an equal partition, and Figure B, which represented an unequal partition. They were asked to cut, arrange, and compare the pieces.

The findings showed that students still experienced difficulties in interpreting the condition of equal partitioning. Some students considered Figure B to be a valid representation of a fraction simply because it contained four pieces. This indicated that students tended to focus on the number of parts rather than on whether the parts were equal in size.

When asked to explain the relationship between equal partitioning and the cultural value of the *Sura' Doti Wai* carving on the *lindo para*, most students provided very brief responses, such as "because Figure A and Figure B are different." The students had not yet developed a conceptual explanation connecting the cultural idea of fairness and regularity with the mathematical requirement of equal-sized parts.

2.4 Reflection on Cycle 1

The findings of Cycle 1 revealed three major learning obstacles. First, students experienced linguistic obstacles when encountering formal mathematical terminology. Second, students demonstrated misconceptions when interpreting the numerator and denominator of a fraction. Third, students had difficulty understanding equal partitioning when relying solely on static visual representations.

These findings indicated that the initial HLT required revision. The revisions focused on simplifying mathematical language, providing more structured questions, and introducing direct physical activities that could enable students to experience the concept of equal partitioning rather than merely observing it.

3. Results of Cycle 2

Based on the learning obstacles identified in Cycle 1, the HLT and LKPD were revised and subsequently implemented in Cycle 2.

3.1 Improvement in Shape Identification Through Simplified Language

The first revision involved replacing unfamiliar formal mathematical terminology with simpler language that was more accessible to elementary school students. Guided multiple-choice questions were also introduced to reduce unnecessary linguistic barriers.

The change resulted in a clear improvement in students' responses. All students were able to identify the basic shape of the carving as a circular shape. Students no longer provided arbitrary responses such as "square," "rectangle," or "box."

The cultural explanation of fairness and regularity in the carving also helped students establish an initial connection between the cultural context and the mathematical concept. The students began to recognize that, similar to the orderly arrangement of the carving, a fraction requires a fair and orderly division of a whole.

3.2 Fraction Exploration Through Structured Questions

The second revision transformed the lengthy open-ended questions into shorter and more structured fill-in-the-blank questions. For example, students were guided through statements such as, "The number 1 in the fraction means that there are _____ parts that are colored."

The revised format made the mathematical information easier for students to identify. However, some students still demonstrated visual bias when interpreting the fraction. Several students continued to focus on the uncolored sections rather than relating the selected part to the total number of parts. Some students even

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responded with the number "4" when asked to determine the fraction.

This finding indicates that simplifying the language alone was not sufficient to completely eliminate the misconception. Teacher guidance remained necessary to emphasize that the denominator represents the total number of equal parts in the whole.

3.3 Developing Understanding Through Hands-on Activity

The most significant change in Cycle 2 involved replacing static visual observation with direct physical activity. Students cut the pieces of Figure A and Figure B, arranged them, and stacked the pieces to compare their sizes.

This activity provided students with direct evidence of the difference between equal and unequal partitions. When the pieces of Figure B were stacked, the students could see that they did not fit or overlap evenly. Through this experience, students were able to conclude that Figure B did not represent a proper fraction because its parts were not equal in size.

The finding demonstrates that physical manipulation supported students in moving beyond merely counting the number of parts toward examining the relationship among the parts. Thus, the revised HLT provided a more concrete pathway for developing students' understanding of the essential condition of fractions.

4. Overall Development of the HLT

The comparison between the two cycles shows that the learning trajectory became progressively more effective after the identified learning obstacles were addressed. The initial HLT relied heavily on visual observation, formal mathematical language, and open-ended questions. The revised HLT incorporated simpler language, guided questions, and hands-on activities.

The resulting learning trajectory can be summarized as a movement from cultural recognition → identification of the whole → representation of parts → comparison of parts → verification of equal partitioning → formalization of the fraction concept.

This trajectory indicates that the *Sura' Doti Wai* context can function not merely as an illustration but as a meaningful starting point for students to construct an understanding of fractions from a familiar cultural context toward a more formal mathematical representation

DISCUSSION

The findings of this study indicate that the development and revision of the *Hypothetical Learning Trajectory* (HLT) through the ethnomathematical context of the Mamasa traditional carving *Sura' Doti Wai* contributed to students' understanding of fundamental fraction concepts. The learning process demonstrated that students' difficulties were not solely caused by the mathematical concepts themselves but also by the language used in the learning materials, the form of task presentation, and the limited opportunities for students to interact directly with concrete representations. The comparison between Cycle 1 and Cycle 2 provides important evidence that an effective learning trajectory needs to be continuously adapted to students' actual thinking and learning obstacles.

The Role of Local Cultural Context in Fraction Learning

The use of *Sura' Doti Wai* provided a meaningful starting point for introducing fractions. Rather than immediately presenting fractions through numerical symbols, students were first encouraged to observe a cultural object that was familiar within their local environment. The regular and symmetrical pattern of the carving provided a visual representation of a whole and its constituent parts. In this way, the cultural object functioned not merely as an illustration but as a context through which students could construct the meaning of fractions.

The findings support the view that mathematics learning becomes more meaningful when students are given opportunities to connect mathematical ideas with contexts that are familiar to them. In the present study, the concept of fairness and balance embedded in the arrangement of the carving could be associated with the mathematical principle of dividing a whole into equal parts. Students could gradually recognize that the same principle of balance found in the cultural context is also required when constructing a fraction.

The cultural context also helped position mathematics as part of students' everyday environment rather than as an isolated school subject. The use of *Sura' Doti Wai* created an opportunity for students to recognize that mathematical ideas can be found in cultural practices and objects around them. Therefore, ethnomathematics in this study served two complementary purposes: supporting conceptual understanding and strengthening students' awareness of local cultural values.

Learning Obstacles Related to Mathematical Language

One of the most prominent findings in Cycle 1 was students' difficulty in understanding formal mathematical terminology. Terms such as *plane figure* and *circular region* caused confusion even though the visual objects themselves were relatively familiar to the students. Some students responded with everyday terms such as "box," "square," or "rectangle," indicating that the problem was not necessarily their inability to recognize the shape but rather their difficulty in connecting the formal mathematical vocabulary with the object they observed.

This finding suggests that mathematical language can become a learning obstacle when formal terminology is introduced without sufficient connection to students' existing language and experiences. For elementary school students, particularly those learning mathematics through concrete objects, the transition from everyday language to formal mathematical language needs to be gradual.

The revision of the HLT in Cycle 2 addressed this obstacle by simplifying the language and providing guided answer choices. The use of familiar expressions such as "round" or "circular" allowed students to focus on identifying the mathematical characteristics of the object rather than struggling with unfamiliar terminology. The students' improved responses indicate that language adaptation was an important component of the revised learning trajectory.

However, simplifying language should not be understood as eliminating formal mathematical terminology. Instead, informal language can function as an initial bridge toward formal mathematical concepts. After students have constructed an intuitive understanding of the object, the teacher can gradually introduce the appropriate mathematical terms. This process can support the

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transition from students' informal reasoning to formal mathematical knowledge.

Students' Misconceptions in Interpreting Fraction Representations

Another important finding concerned students' misconceptions when determining the value of a fraction from a visual representation. In Cycle 1, several students compared the shaded portion with the unshaded portion rather than with the total number of equal parts. Some students also focused directly on the number of unshaded parts or provided the number of parts as their answer.

This finding indicates that students had not yet fully understood the relationship between the numerator and denominator. The denominator should represent the total number of equal parts into which the whole is divided, while the numerator represents the number of selected or shaded parts. Students' responses showed that they tended to interpret the visual representation perceptually rather than structurally.

The revision of the HLT attempted to address this difficulty by replacing lengthy open-ended questions with shorter and more focused prompts. The use of fill-in-the-blank questions helped reduce the reading burden and directed students' attention to specific components of the fraction. Nevertheless, the results of Cycle 2 showed that the misconception did not disappear completely. Some students continued to focus on the unshaded portion or on the visible number of parts.

This finding is important because it demonstrates that modifying the wording of a task alone may not be sufficient to overcome a conceptual misconception. Students may require explicit teacher questioning and opportunities to manipulate representations so that they can distinguish between the whole, the selected part, and the remaining part. Thus, the HLT should anticipate not only language-related obstacles but also perceptual and conceptual obstacles that may emerge from students' interpretation of visual representations.

The Importance of Hands-on Activities in Understanding Equal Parts

The most significant improvement occurred in the learning activity related to the requirement that the parts of a fraction must be equal in size. In Cycle 1, students were asked to compare two static images: one representing an equal partition and another representing an unequal partition. Although the number of parts in both images was the same, several students considered both representations to be valid fractions. This response indicates that students were primarily using the number of parts as their criterion rather than considering whether the parts were equal in size.

The revised HLT introduced a concrete and enactive activity in which students cut, stacked, and compared the parts of the two images. This modification provided students with direct physical evidence of the difference between equal and unequal partitions. When the pieces were stacked, the unequal pieces could not completely overlap. Through this experience, students were able to discover the meaning of "equal parts" through action rather than merely through visual observation.

The change from static observation to hands-on activity represents an important development in the learning trajectory. Students were no longer simply asked to accept the statement that fractions require equal parts; instead, they were given an opportunity to investigate and verify the principle themselves. Their ability to conclude that the unequal division did not satisfy the requirement of a fraction suggests that concrete manipulation helped students develop a more stable conceptual understanding.

This finding also demonstrates the importance of anticipating students' learning processes in an HLT. The initial conjecture assumed that students would be able to identify equal and unequal parts through visual comparison. Classroom evidence showed that this assumption was too optimistic. The revised HLT therefore incorporated a more concrete activity that corresponded to the actual level of students' reasoning.

Development of the HLT Through Iterative Design

The comparison between the two cycles demonstrates the central characteristic of *design research*, namely the iterative relationship between theoretical design and empirical classroom evidence. The initial HLT was developed based on predictions regarding students' thinking. However, the actual implementation revealed learning obstacles that were not fully anticipated. These obstacles became the basis for revising the learning trajectory.

In Cycle 1, the main obstacles included difficulties with mathematical terminology, misconceptions in interpreting fraction representations, and difficulties in recognizing equal-sized parts through static visual representations. The revisions in Cycle 2 were therefore directed toward these specific obstacles. The mathematical language was simplified, task instructions were shortened and structured, and physical manipulation was introduced.

The results of Cycle 2 show that the revised HLT was more responsive to students' actual learning needs. The improvement was particularly evident in students' ability to identify the geometric form and understand the principle of equal partitioning. This confirms that an HLT should not be regarded as a fixed lesson plan. Rather, it should be understood as a flexible conjecture about how students may learn a particular concept and should be continuously refined based on classroom evidence.

The iterative process also strengthens the relationship between students' informal knowledge and formal mathematical concepts. In this study, students began with a familiar cultural object, explored its parts, experienced the principle of fairness through concrete activities, and gradually connected these experiences to the formal idea of fractions. Such a progression reflects the importance of designing learning trajectories that move from contextual and concrete experiences toward more formal mathematical representations.

Implications for Mathematics Learning Through Ethnomathematics

The findings of this study have several implications for elementary mathematics education. First, local cultural objects can be used as meaningful contexts for introducing abstract mathematical concepts. The *Sura' Doti Wai* carving provided students with a culturally relevant representation of a whole and its parts and allowed the concept of equal partitioning to be discussed in relation to the cultural value of fairness and balance.

Second, teachers need to consider students' language and cognitive readiness when designing mathematical tasks. Formal terminology should be introduced gradually and supported by familiar words, concrete objects, visual representations, and guided questions.

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Third, conceptual learning should provide opportunities for students to manipulate objects and test their own ideas. In the present study, the cutting and stacking activity was more effective in helping students understand equal parts than static visual observation alone.

Finally, the findings suggest that ethnomathematics should not be limited to using cultural objects as decorative or contextual elements. The cultural context needs to contain and reveal mathematical relationships that can be explored by students. In *Sura' Doti Wai*, the ideas of symmetry, balance, proportion, whole-part relationships, and fairness provided meaningful entry points for developing the concept of fractions.

Overall, the study demonstrates that the integration of *Sura' Doti Wai* into an HLT can support the development of meaningful fraction learning. The effectiveness of the approach, however, depends on the quality of the learning trajectory, the teacher's ability to respond to students' thinking, and the provision of appropriate concrete experiences. Therefore, the main contribution of this study lies not only in the use of a local cultural artifact but also in the iterative development of a learning trajectory that responds to students' actual learning obstacles.

CONCLUSION

This study developed and implemented a *Hypothetical Learning Trajectory* (HLT) for learning fraction concepts through the ethnomathematical context of the Mamasa traditional carving *Sura' Doti Wai*. The findings demonstrate that the initial HLT required refinement because students encountered several learning obstacles during the first cycle. These obstacles included difficulties in understanding formal mathematical terminology, misconceptions in interpreting fraction representations, and difficulties in recognizing the requirement that the parts of a whole must be equal in size.

The initial HLT consisted of three main stages: cultural orientation through the observation of the *Sura' Doti Wai* carving, exploration of fraction representations through coloring activities, and analysis of the equal-part requirement through visual comparison. The implementation of this initial trajectory provided important information about students' actual ways of thinking and became the basis for revising the learning trajectory.

The revised HLT incorporated several improvements. Mathematical terminology was simplified and connected to students' everyday language, lengthy open-ended questions were transformed into shorter and more guided tasks, and visual observation was complemented by concrete hands-on activities. In particular, cutting, stacking, and comparing the parts of the figures enabled students to directly examine whether the parts were equal in size.

The implementation of the revised HLT in Cycle 2 showed improved student understanding. Students were able to identify the basic geometric form represented in the carving, recognize the relationship between a whole and its parts, and understand that a fraction requires a whole to be divided into equal-sized parts. Although some students still demonstrated visual difficulties when determining fraction values, the learning obstacles identified in Cycle 1 were substantially reduced.

Therefore, the findings confirm that the integration of *Sura' Doti Wai* as an ethnomathematical context can provide a meaningful and concrete starting point for learning fractions in elementary school. More importantly, the iterative development of the HLT enabled the learning design to respond to students' actual thinking and learning obstacles. The study suggests that culturally relevant contexts, combined with concrete activities and carefully designed learning trajectories, can support students in constructing a deeper and more meaningful understanding of mathematical concepts.

APPENDIX

Appendix A. Hypothetical Learning Trajectory (HLT)

Stage	Learning Activity	Expected Student Thinking
1. Cultural Orientation	Students observe the Sura' Doti Wai carving and identify its basic shape and whole form.	Students recognize the carving as a whole object and identify its basic geometric form.
2. Fraction Exploration	Students color parts of the carving and identify the numerator and denominator.	Students understand the relationship between the whole and its parts.
3. Equal Parts	Students cut, stack, and compare parts of the figure.	Students understand that a fraction represents a whole divided into equal-sized parts.

Appendix B. Learning Obstacles and HLT Revision

Learning Obstacle	Revision in HLT
Students had difficulty understanding formal mathematical terminology.	Mathematical language was simplified and connected to familiar terms.
Students compared shaded and unshaded parts instead of relating the part to the whole.	Guided questions were added to strengthen the part-whole relationship.
Students had difficulty recognizing equal-sized parts from static images.	Concrete activities involving cutting, stacking, and comparing parts were introduced.
Students had difficulty responding to lengthy open-ended questions.	Questions were shortened and changed into more guided tasks.

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