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Learning Design for Translation Concepts Using Bola Kasti Games

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ABSTRACT

Students often struggle to grasp geometric transformation concepts, particularly translation. Although some students can recognize object movement visually, conceptual misconceptions persist in interpreting the meaning of displacement, along with difficulties in representing movement visually using Cartesian diagrams. This condition indicates the need for a more contextually and meaningfully grounded learning approach that connects mathematical concepts with activities familiar to students. In this study, the traditional game of *bola kasti* is employed as an effective learning medium, serving as a cultural activity that is relevant and closely related to students' experiences. The traditional *bola kasti* game functions not merely as a contextual illustration but is systematically designed as a conceptual transition tool that bridges physical activities and formal coordinate representations in the concept of translation. This research aims to develop a learning trajectory using the PMRI approach, incorporating the context of the *bola kasti* game to support students in constructing a deep understanding of the concept of translation. The research employed a design research methodology with a validation study type, involving 32 ninth-grade students from SMP Negeri 52 Palembang. Data collection techniques included student activity sheets, classroom observations, and interviews, which were analyzed descriptively using a qualitative approach. The findings indicate that the Actual Learning Trajectory (ALT) aligns with the designed Hypothetical Learning Trajectory (HLT). Therefore, the developed HLT is considered successful and contributes to the development of a Local Instructional Theory (LIT) in enhancing students' conceptual understanding progressively, as demonstrated by students' ability to identify the direction and magnitude of translation and to represent translations using Cartesian diagrams through the PMRI approach with the context of the *bola kasti* game in translation learning.

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Introduction

Mathematics is a discipline that holds a pivotal role within the educational system. It is introduced at an early age, beginning in elementary school and continuing through secondary education (Nurmaya, 2021). Despite its importance, mathematics instruction is often perceived as abstract and detached from students' lived experiences. At the junior secondary level, geometry constitutes a core component of the mathematics curriculum, with geometric transformations identified as one of the essential topics. At this stage, students are expected to perform single transformations on the Cartesian coordinate plane and apply these skills to problem-solving contexts (Permendiknas No.22 Tahun 2016).

A sound understanding of geometric transformation concepts is fundamental for learners, as it provides an important basis for solving problems encountered in everyday life (Surgandini et al., 2019). However, students frequently experience substantial challenges in mastering these concepts, particularly the concept of translation (Luvy, 2020; Rosyada et al., 2025) Students encounter difficulties understanding translation concepts because this topic requires representing the displacement of an object on the coordinate plane without direct, concrete observation of the movement process, which often results in representational errors in translation tasks. (Ni'matul Ula & Hadi, 2023; Surya et al., 2021).

Additional difficulties arise when students are required to determine the direction and magnitude of a translation, particularly when connecting horizontal and vertical shifts, indicating the persistence of conceptual misunderstandings in students' learning of translation (Samaran et al., 2024). Although some students are able to identify the displacement of an object visually, they still encounter obstacles in relating this displacement to real-world situations or in comprehending its conceptual meaning (Nurmaya, 2021; Rosyada et al., 2025; Wasilah et al., 2023). These conditions underscore the need for a more contextual and engaging instructional approach, one that effectively bridges mathematical concepts with activities that are familiar and meaningful to students.

The Indonesian Realistic Mathematics Education (PMRI) approach serves as a relevant alternative for bridging the gap between abstract mathematical concepts and students' real-life experiences (Fitra, 2018; Tamimi et al., 2025; Zaini & Marsigit, 2014). PMRI is developed based on the principles of Realistic Mathematics Education (RME) from the Netherlands, which emphasizes that mathematics instruction should begin with 'realistic' situations, contexts that are imaginable or closely connected to students' lived experiences (Fauziah et al., 2020; Van Zanten & Van den Heuvel-Panhuizen, 2021; Zulkardi & Putri, 2019). By incorporating contexts rooted in students' everyday lives, PMRI enables learners to construct mathematical understanding through processes of exploration, discussion, and reflection, ensuring that the concepts acquired are not merely procedural but also meaningfully conceptual (Gravemeijer & Cobb, 2006; Sam et al., 2025; Sembiring et al., 2008; Zulkardi & Putri, 2019).

In the context of teaching translation, the traditional game bola kasti can serve as an effective instructional medium. Activities within the game, such as the movement of players from one base to another, provide a concrete representation of the concept of point displacement, as they involve clear, measurable, and easily visualized patterns of movement on a coordinate plane (Fajria Septiani, 2024). By integrating this game into the instructional design, students are expected to develop a deeper understanding of translation, beginning with identifying the displacement, determining pairs of initial and final points, and ultimately representing the displacement in formal mathematical terms (Doorman, 2019; Fajria Septiani, 2024; Gravemeijer & Cobb, 2006).

Several previous studies have been conducted, including the work of Rosyada et al. (2025) which employed a cinema context in teaching translation. Additionally, various researchers have incorporated local contexts in designing learning activities on translation. For

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instance, Lestari et al. (2021) utilized the Sam Poo Kong Temple in Semarang, Hamidah et al. (2024) integrated the Red Mosque of Cirebon, and Nursyahidah et al. (2020) used historical buildings in Central Java. Other studies have explored cultural contexts, such as the research by Faiza & Aziz (2024) which connected the teaching of geometric transformations with ethnomathematics. Furthermore, Novianti et al. (2025) employed Dayak dance floor patterns as a contextual basis. However, a review of previous studies indicates a lack of instructional designs that support students in representing object displacement using Cartesian diagrams.

In light of these considerations, this study develops learning activities designed to enhance students' representational abilities and conceptual understanding of translation through the integration of the traditional bola kasti game as a contextual learning medium for ninth-grade students. This study employed design research of the validation study type to develop and validate learning activities on translation. The proposed instructional design was validated through expert focus group discussions (FGDs) and iterative limited implementations, including pilot and teaching experiments, to analyze the correspondence between the designed Learning Trajectory and students' emergent reasoning strategies. The design is expected not only to support students in understanding the concept of translation in a more concrete and meaningful manner, but also to enhance their learning motivation through engaging activities that are relevant to their everyday experiences.

Method

Design Research

The research method employed in this study is design research of the validation study type, aimed at designing and validating a Hypothetical Learning Trajectory (HLT) and learning activities on the topic of translation using a *bola kasti* game as the learning context. This method was selected because the study does not merely focus on developing an instructional design but also on empirically examining the alignment between the proposed learning trajectory and students' responses as well as their thinking strategies (Plomp & Nieveen, 2013). The research process consists of three phases: Preliminary Design, Design Experiment, and Retrospective Analysis (Doorman, 2019; Gravemeijer & Cobb, 2006; Plomp & Nieveen, 2013).

Preliminary Design

In the first phase, the preliminary design stage, an in-depth literature review was conducted regarding the topic of translation and the development of PMRI-based activity sheets using meaningful contexts in mathematics learning. Based on the outcomes of this phase, the researchers designed an HLT that includes learning objectives, learning activities incorporating the bola kasti game, as well as anticipated student responses and strategies during the learning process. During the preparation stage, a focus group discussion (FGD) was also conducted to obtain expert feedback on the proposed HLT. The HLT is designed to be dynamic, allowing it to evolve and adapt throughout the learning experiment.

Design Experiment

The second phase, the design experiment, consists of two cycles: the pilot experiment and the teaching experiment. In the first cycle, the pilot experiment, the initial HLT was tested on a small group of six students. This trial aimed to identify limitations or weaknesses in the initial HLT design. Based on the findings from this cycle, the researchers refined the HLT to better align with students' characteristics and learning needs. The revised HLT was then implemented in the second cycle, the teaching experiment, which involved the entire class as research participants, consisting of 32 ninth-grade students from SMP Negeri 52 Palembang.

Analyzed Retrospectively

The data were subsequently analyzed retrospectively to compare the initial assumptions in the HLT with the actual learning trajectory (ALT) observed during the instructional activities. The results of this analysis were then used to formulate a Local Instruction Theory (LIT), which serves as a guideline for designing and developing future learning activities. Data collection in this study included student activity sheets, classroom observations, and interviews. Observations were conducted to examine students' activities during the learning process, including their responses, interactions, and strategies for completing tasks related to understanding the concept of translation. Meanwhile, interviews were used to clarify students' reasoning and to gather additional information that could not be captured during classroom activities. All data were analyzed qualitatively using descriptive techniques, referring to the initially designed HLT, with the purpose of refining the HLT to ensure that it becomes more effective and better aligned with students' learning needs.

Research Findings

In this study, the instructional process was carried out through two learning activities designed using the bola kasti game to support students in understanding the concept of translation. The following section presents the stages of developing the HLT using the bola kasti game.

Preliminary Design

During the preparation phase of the experiment, a literature review was conducted on the junior high school curriculum related to translation, the theoretical foundations of the PMRI approach, and the use of meaningful contexts that can be directly experienced by students in mathematics learning (Putri et al., 2015; Rosyada et al., 2025). The results obtained in this phase were then used to design the initial HLT, which consisted of three components: learning objectives, learning activities, and the construction of the instructional design in the form of an HLT (Hamidah et al., 2024). Subsequently, a focus group discussion (FGD) was carried out to gather expert feedback aimed at improving the quality of the HLT and the student activity sheets that had been developed (Walid et al., 2025). Based on the input gathered from the FGD with PMRI course instructors and colleagues, several minor revisions were made to the student activity sheets, including simplifying instructional statements, adding explanatory notes on translation to assist students in identifying the displacement of translated points, and adding an activity prompting students to formulate conclusions and derive the formal expression of translation. The HLT designed by the researchers is presented in Table 1.

Table 1. HLT Using the Bola Kasti Game

Learning Goal	Learning Activities	Conjecture
Students can analyze the *bola kasti* game as an entry point for understanding the concept of translation.	Students who represent each group participate in the *bola kasti* game, while those who are not directly involved observe the activity and analyze the movement of the players from the batter's point (initial	• Students can understand the displacements occurring during the *bola kasti* game in accordance with the predetermined directions of movement

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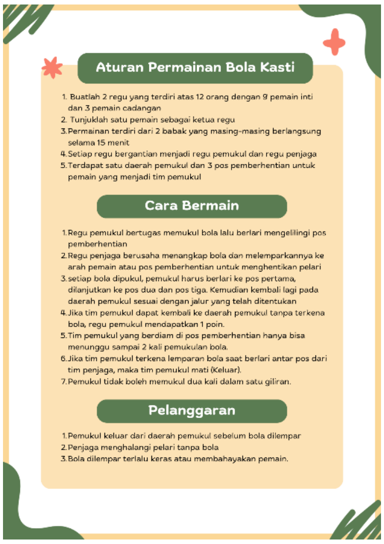
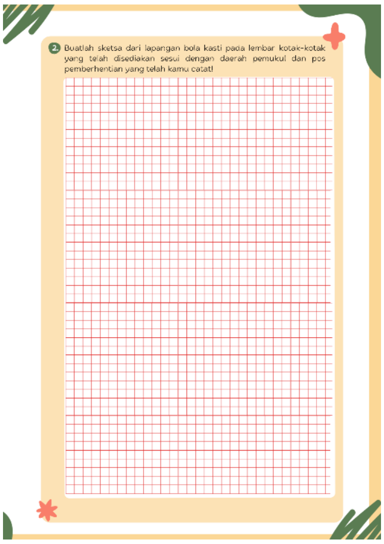
	point) to third base and back to the batter's point (initial point).	(right, left, forward, and backward).



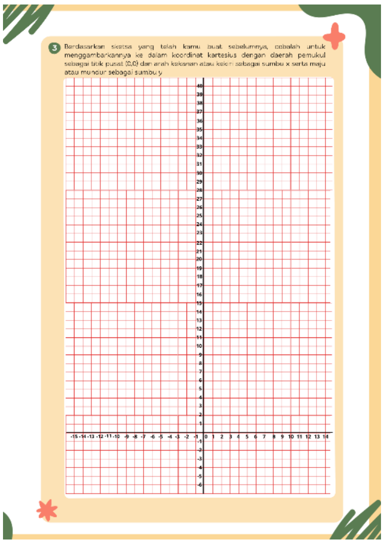
Students are able to determine the displacement from the batter's point as the initial point to be translated, to third base, and then back to the batter's point, based on the direction and number of steps taken.	Students determine and record the displacement from the batter's point to first base, then to third base, and back to the batter's point by using the number of steps taken in accordance with the predetermined directions.	• Students are able to record each displacement by counting the number of steps taken by the player in accordance with the direction of movement, starting from the batter's point to the third base and then back to the batter's point.

Students are able to construct the observed movements in the form of a field sketch of the kasti game that accurately represents the directions and steps taken throughout the activity.	Students sketch of the kasti game field.	• Students can sketch of the kasti game field on the provided grid paper, with each square representing one step.



Students can represent each movement that occurs during the kasti game in the Cartesian coordinate system.

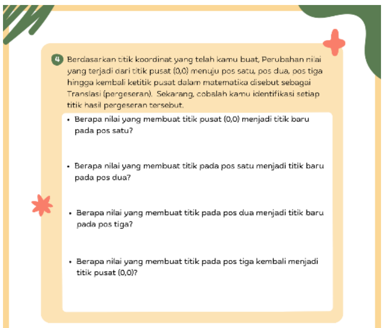
Students plot the batter's point (initial point) and each base on the Cartesian coordinate system according to the direction and distance of movement previously illustrated in the sketch.



- Students can represent the sketch previously created on a Cartesian coordinate system from the batter's point to first base.
- Students can represent the movement from the first base to the second base on the Cartesian coordinate system.
- Students can represent the movement from the second base to the third base on the Cartesian coordinate system.
- Students can represent the movement from the third base back to the batter's point (initial point) on the Cartesian coordinate system.

Students are able to identify the relationship between the coordinates of the batter's point (initial point) and the translated points at base 1, base 2, base 3, and back to the batter's point (initial point).

Students identify the changes in values resulting from all movements that have occurred.



- Students can identify the changes in values that occur in accordance with the predetermined directions in the game (right or left as the x-axis, and forward or backward as the y-axis).
- Students can recognize that the changes in values result from adding the corresponding values representing the x- and y-axes.

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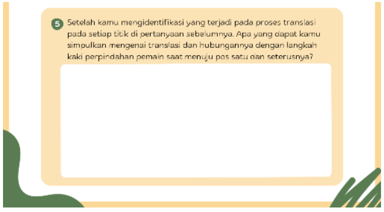
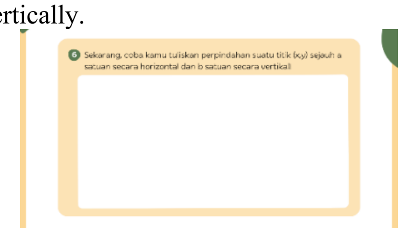
Students are able to formulate a conclusion regarding their understanding of the concept of translation based on the activities in the rounders game.	Students are able to conclude an understanding of the concept of translation based on the activities they have carried out.  	• Students can conclude the concept of translation based on the rounders game activities they have conducted. • Students understand that translation is the movement of a point to another point, determined by a specific direction (right or left representing the x-axis, and forward or backward representing the y-axis).
Students are able to rediscover the concept of translation in its formal mathematical form.	Students can rediscover the concept of translation more abstractly and formally by expressing the displacement of a point (x, y) by a units horizontally and b units vertically.  	• Students can express the formal notation of the translated coordinates in the form $(x + a, y + b)$. • Students can informally represent the translated coordinates.

Design Experiment

Pilot Experiment

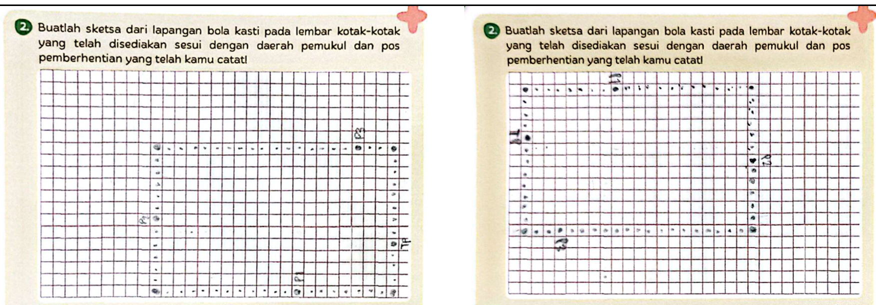
In the first cycle, namely the pilot experiment, six students were involved in testing the HLT that had been designed during the preliminary design phase. In this cycle, the students participated in a physical activity by playing bola kasti and completing a student activity sheet consisting of one activity with five questions. After completing the bola kasti game, the students were asked to answer questions related to the displacements that occurred, based on the number of steps taken and the predetermined directions during the game, and to record their answers on the worksheet provided. The students' responses are presented as follows.

Student 1 Student 2

Figure 1. Students' Responses to Question 1 in Cycle 1

Based on Figure 1, it can be seen that both Student 1 and Student 2 were able to record the displacement based on the number of steps taken and the predetermined directions during the game. However, their responses show differences in the number of steps for each displacement. These differences occurred because, during the observation and identification of the rounders game, each player took steps that varied in length and number. Consequently, each student produced different calculations of the total steps taken. This variation in the number of steps subsequently resulted in diverse translated points for each student, corresponding to their individual calculations of the displacement.

In the second question, students were asked to create a sketch of the rounders game based on their identification of the player's displacement, represented by the number of steps taken, on graph paper. Each square on the grid represented one step. The purpose of this activity was to enable students to illustrate each displacement made by the player from the batting point to each base and back to the batting point. The students' sketches of the rounders game can be seen in Figure 2.

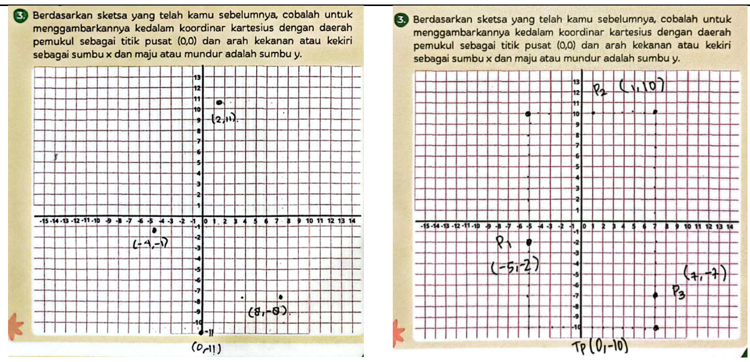


Student 1 Student 2

Figure 2. Students' Responses to Question 2 in Cycle 1

Based on the sketch of the rounders game shown in Figure 2, both Student 1 and Student 2 were able to represent each point resulting from the player's displacement, beginning from the initial point to the second base. This was followed by the displacement from the second base to the third base, and finally from the third base back to the initial point. These results indicate that the students understood and were able to identify each displacement point that occurred throughout the rounders game.

After constructing the sketch of the rounders game, the third question required students to redraw their sketch on a Cartesian coordinate plane, with the batting point serving as the starting point of the game placed at the coordinate (0,0). This activity aimed to enable students to represent the coordinates of each point resulting from the displacements that occurred during the game. The students' work for this activity is presented in Figure 3.



Student 1 Student 2

Figure 3. Students' Responses to Question 3 in Cycle 1

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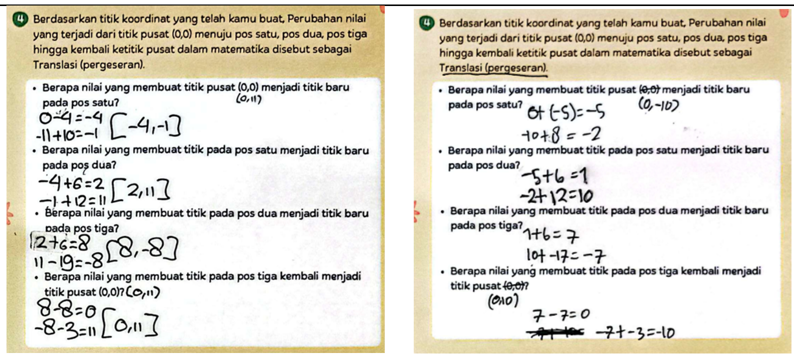
In this activity, a slight adjustment occurred in which the batting point, initially positioned at the coordinate (0,0), was shifted to the lowest point on the y-axis. This change was necessary because the number of displacements exceeded the range of the provided coordinate grid. As shown in Figure 3, Student 1 began the initial point at the coordinate (0,–11), while Student 2 started at (0,–10). During this activity, some students experienced confusion. When drawing the sketch, students were supported by grid paper in which each box represented one step. However, when transferring the sketch onto the Cartesian coordinate plane, students needed to match the number of steps taken during the displacement with the corresponding coordinates. The confusion particularly emerged when representing the displacement from the initial batting point (0,–11) to the first base, which involved 4 steps to the left and 8 steps forward. Students assumed that the numbers 4 on the x-axis and 8 on the y-axis directly represented the new coordinate of the displacement. In fact, they were expected to translate the point initially located at (0,–11) by moving it 4 units to the left on the x-axis and 8 units upward on the y-axis, resulting in the coordinate (–4, –3) for the first base.

In the fourth question, students were asked to identify the changes in values resulting from each displacement. This question was designed to guide students in discovering the concept of translation, namely that the new coordinate of a point after displacement is obtained by adding the initial coordinate to the number of steps taken. Horizontal movements (to the right or left) correspond to changes on the x-axis, while vertical movements (upward or downward) correspond to changes on the y-axis. The results of the students' identification can be seen in Figure 4.



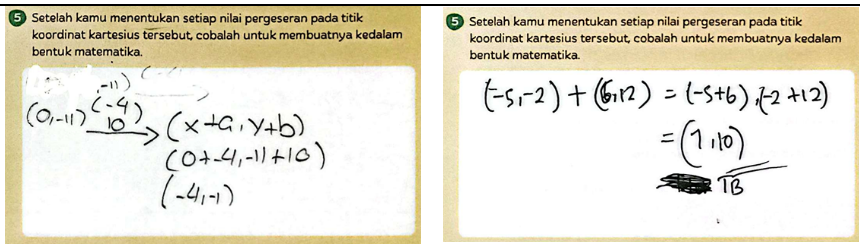
Student 1 Student 2

Figure 4. Students' Responses to Question 4 in Cycle 1

Based on Figure 4, differences can be observed between the responses provided by Student 1 and Student 2. In Student 1's response, it appears that the student immediately treated the horizontal displacement on the x-axis as a subtraction operation ($0 - 4 = -4$). Although the final answer is correct, the computational reasoning contains a misconception. The negative sign in "−4" does not indicate a subtraction operation; rather, it represents a negative value. The coordinate resulting from the displacement from the batting point to the first base should be (−4, −1), indicating that the point lies in the negative region of both the x- and y-axes.

Meanwhile, the response provided by Student 2 is accurate. Student 2 correctly applied addition when calculating the displacement for each point. Furthermore, the student demonstrated an understanding that the Cartesian coordinate system includes both positive and negative values on the x- and y-axes. However, Student 2 did not rewrite the final coordinates in the formal ordered-pair notation (x, y); instead, the student only listed the results of the addition operations for each translated point.

In the fifth question, students were asked to formulate and write the translation of a point in formal mathematical notation. This question was intended to support students in rediscovering and generalizing the concept of translation into a more abstract form using the symbols (x, y, a, b). The students' responses to this question are presented in Figure 5.



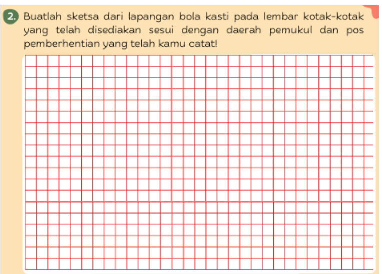
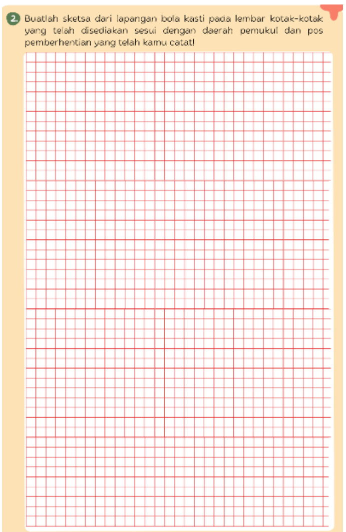
Student 1 Student 2

Figure 5. Students' Responses to Question 5 in Cycle 1

In this question, most students directly wrote the formula for the concept of translation. However, based on Figure 5, it can be observed that Student 1 was able to write the formal representation of the translation but did not express it abstractly. This occurred because the student remained focused on the translated points previously obtained. Consequently, the formula written by Student 1 still consisted of the numerical coordinates from the rounders game. Meanwhile, Student 2 was able to write the translation formula informally, directly adding the coordinates from the rounders game without using symbolic notation for the point coordinates (x, y) in the translation.

The students' work from Cycle 1 was used as a basis for evaluating and revising the sequence of questions on the student activity sheets. The revisions included modifications to the students' answer sheets for Questions 2 and 3. Additionally, Question 5 was split into two separate questions to better guide students in concluding and generalizing the concept of translation more abstractly. The revised student activity sheets are presented in Table 2.

Table 2. Cycle 1 Student Activity Sheet Revisions

Before Revision	After Revision	Revision
Question 2		
		The students' answer sheets used to illustrate the displacement from each station were enlarged.
Question 3		
		The Cartesian diagram in the third question was extended to

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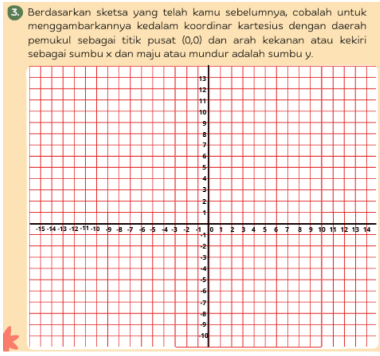
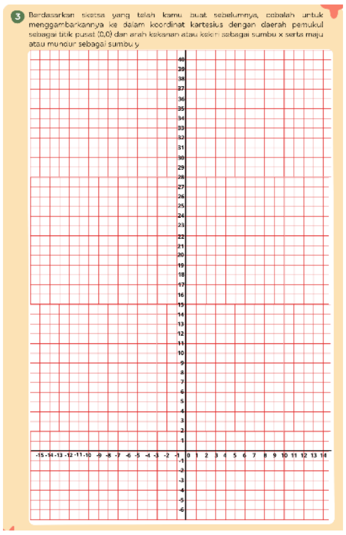
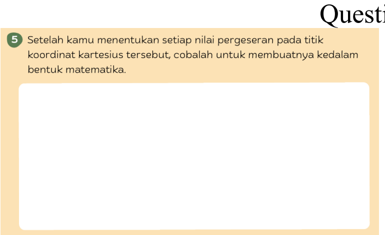
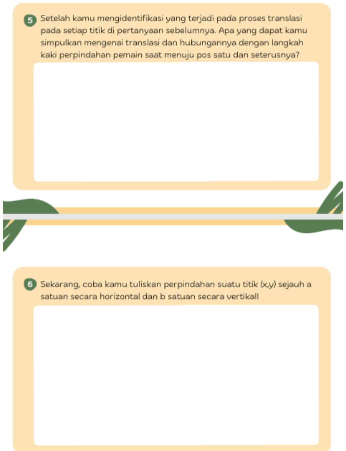




accommodate the field area that students might represent

Question 5





The fifth question was reformulated into two questions to guide students in deriving the formal representation of translation.

Teaching Experiment

The second cycle, namely the teaching experiment, involved 32 students divided into six learning groups. At the beginning of the lesson, each group sent two representatives to participate in the bola kasti game, while the students not actively playing were responsible for observing and identifying the movements in the game. After the bola kasti game concluded, each group completed the student activity sheets based on the information they had gathered during the game.

In the first question, students were asked to record the number of steps taken by the players from the batter’s point to the first, second, and third bases, and back to the batter’s point. This question served as a starting point for students to discover and understand the concept of translation through a real-life situation before moving toward more abstract representations. The students’ responses can be seen in Figure 6.

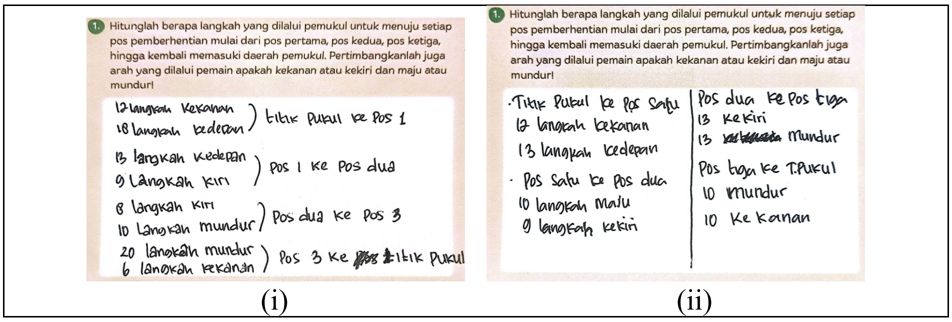


Figure 6. Students' Responses to Question 1 in Cycle 2

Based on Figure 6, differences can be observed between Groups (i) and (ii). These differences arose because each player's step length varied, resulting in discrepancies in the total number of steps calculated by each group according to their own observations and identifications. Nevertheless, the researcher's observations indicated that all groups were still able to determine each displacement accurately, as students could calculate the displacements directly.

After all groups recorded the displacements that occurred, students were then asked to sketch the bola kasti game they had played. This question aimed to enable students to illustrate and represent each displacement according to the predetermined directions during the game. The responses to this question are shown in Figure 7.

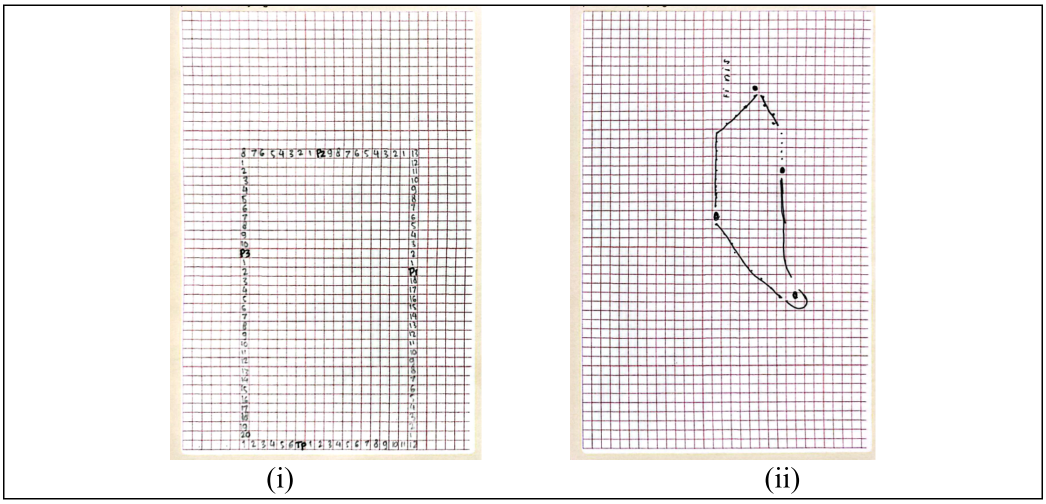


Figure 7. Students' Responses to Question 2 in Cycle 2

When sketching the bola kasti game, neither the initial point nor the center of the field was predetermined. Students were only informed that each square on the sheet represented one step. Therefore, students had the freedom to create the game sketch according to their understanding gained from the experience of playing bola kasti.

Based on Figure 7, it can be seen that each group produced a different sketch. In Figure 7(i), the group assumed that the starting point or batter's position was located in the main area of the field, so they drew the sketch at the bottom row of the grid sheet. In contrast, in Figure 7(ii), another group assumed that the player who would move was positioned on the right side of the field. Moreover, they depicted the player's movement not along the square edges of the field but following other directions they considered more appropriate to represent the game situation.

In the third question, students were asked to transfer the sketch they had created onto a Cartesian coordinate system, using the batter's point as the origin (0,0). This step aimed to help

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students understand each displacement from the batter's point to the first, second, and third bases, and back to the batter's point in a more abstract manner through the coordinate representation of each base. The Cartesian coordinates produced by the students are presented in Figure 8.

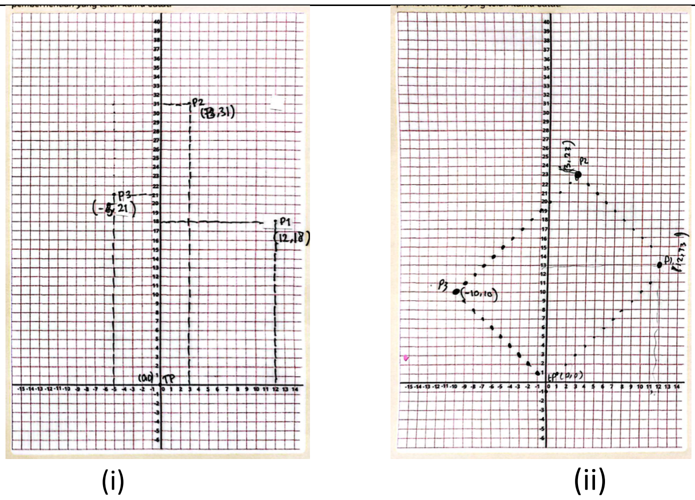

Figure 8. Students' Responses to Question 3 in Cycle 2

When plotting the Cartesian coordinates, each group adjusted the displacements according to the step directions recorded in Questions 1 and 2. Based on Figure 8, it can be seen that each group was able to represent the sketch of the bola kasti game on the Cartesian coordinate system effectively. Differences between groups are apparent in Figure 8(i), where the group only recorded the coordinate points representing each base. The first displacement from the origin (0,0) to the first base is (12,18). The subsequent displacement from the first base to the second base is (3,31), followed by the movement to the third base, resulting in the coordinate (–5,21).

Meanwhile, the responses of the group shown in Figure 8(ii) indicate that the origin (0,0) was shifted to a new point at the first base with coordinates (12,13). The next displacement moved the point to the second base at (3,23), and then to the third base at (–10,10). These differences in translated coordinates arose from variations in the number and direction of steps based on each group's observations and calculations. Therefore, the results of translation between groups may vary depending on the initial information regarding the number of steps taken during the bola kasti game.

After plotting the Cartesian coordinates, in the fourth question, students were asked to analyze the changes occurring from the initial point to the new points and to relate them to the number of steps and direction of each displacement. This question aimed to help students discover the concept of translation for each displacement, where the changes occur due to shifts of specific distances and directions, resulting in new points created by these displacements. The students' responses to this question are presented in Figure 9.

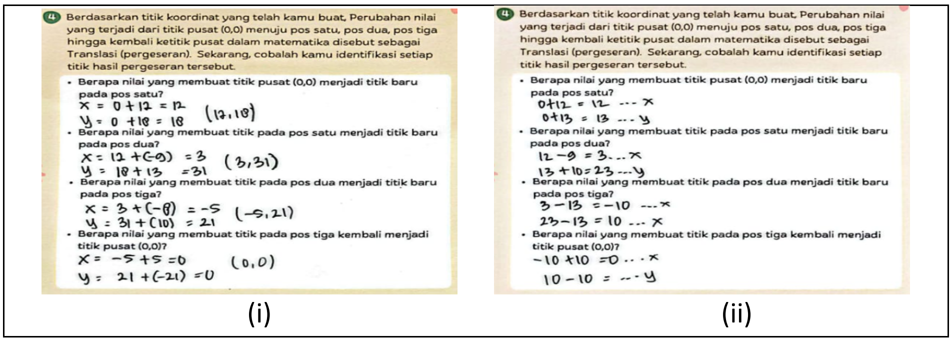

Figure 9. Students' Responses to Question 4 in Cycle 2

As shown in Figure 9, students were able to identify the changes in the values of each coordinate point resulting from the translations. Based on Figure 9(i), it can be seen that the group understood that the change in a coordinate point occurs by adding the initial point to the displacement value, which is represented by the number of steps. Steps moving to the right or left are represented as horizontal shifts on the x-axis, with positive (+) values for rightward movement and negative (–) values for leftward movement. Similarly, steps moving forward or backward correspond to vertical shifts on the y-axis: upward movement is positive (+), while downward or backward movement is negative (–).

In contrast, a different response is shown by the group in Figure 9(ii). This group assumed that changes in horizontal leftward and vertical downward displacements should be performed using subtraction. In fact, the correct operation is addition, where the numerical value is determined by the direction of the translation: positive for horizontal shifts to the right and vertical shifts upward, and negative for shifts to the left and downward. Interviews with the students revealed that this misconception occurred because the students focused too much on the calculation results and overlooked the displacement direction, which determines whether the shift should be positive or negative.

After students understood that translation involves adding the initial point to the displacement, they were asked to conclude their understanding of translation and its relationship with the players' step movements. The students' responses to this question are presented in Figure 10.

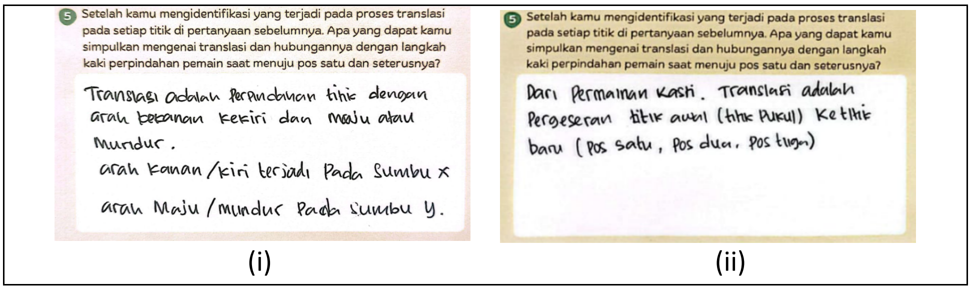

Figure 10. Students' Responses to Question 5 in Cycle 2

As shown in Figure 10, for the fifth question, students were able to understand and conclude the concept of translation from all the activities they had completed. Although the coordinates resulting from the displacements on the Cartesian plane varied depending on each student's step calculations, students were able to recognize that translation involves moving a point to a new location with a specific direction and distance. Horizontal displacements to the right or left affect the position on the x-axis, while vertical displacements upward or downward affect the position on the y-axis.

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Next, students were asked to express the concept of translation in a more abstract form in the sixth question. In this question, students were required to represent the displacement of a point (x, y) by a units horizontally and b units vertically. The purpose of this question was to guide students in rediscovering the concept of translation in a formal representation. The students' responses to this question are shown in Figure 11.

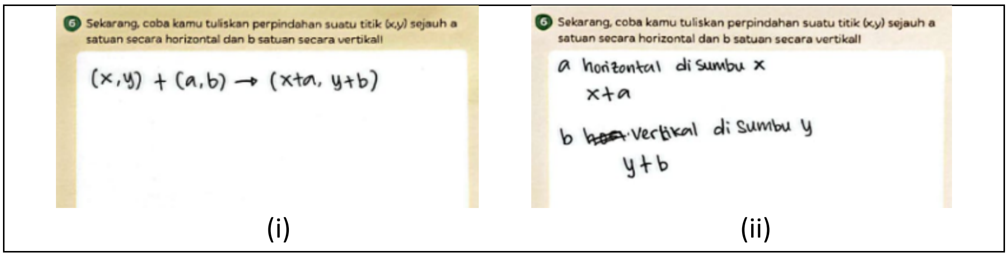

Figure 11. Students' Responses to Question 6 in Cycle 2

Based on Figure 11, it can be seen that students were able to represent point displacements using the concept of translation. Some students were able to express the displacements formally, as shown in Figure 11(i), while others conveyed the concept of translation informally using their own language, as illustrated in Figure 11(ii). Moreover, in this question, students were not only guided to rediscover the concept of translation in a more abstract and formal form, but were also encouraged to strengthen their understanding by generalizing the concept and expressing it formally (Rosyada et al., 2025; Sari & Sari, 2019).

Retrospective Analysis

The data obtained in Cycle 2 were subsequently analyzed retrospectively by comparing the designed HLT with the Actual Learning Trajectory (ALT). The results of this retrospective analysis were used to further develop the HLT until it was deemed sufficient to produce a Local Instruction Theory (LIT) that better aligns with students' needs (Walid et al., 2025). The comparison between the HLT and ALT for the teaching of translation using the bola kasti game is presented in Table 3.

Table 3. Comparison of HLT and ALT in Teaching Translation Using the Bola Kasti Game

Activity	HLT	ALT
Students engage in the *bola kasti* game as a starting point for understanding the concept of translation.	Students are able to identify each player's displacement from the batter's point to first base and back to the batter's point.	Students are able to recognize each player's displacement in the *bola kasti* game.
Students calculate and record the displacements from the batter's point as the starting point to third base and back to the batter's point, based on the direction and number of steps taken by the players.	Students calculate and record the number of steps for each displacement from the batter's point to the third base, based on the step count and direction of each movement.	Students, together with their group members, calculate the number of displacements using steps in the predetermined directions during the game (right, left, forward, backward).
Students construct the displacements that occur in the form of a *bola kasti* field sketch, according to the directions and steps taken during the game.	Students draw a sketch of the *bola kasti* field based on each group's perspective.	Three groups drew rectangular sketches, with each side representing the displacement points of the players (batter's point, first base, second base, and third base). Two groups drew square-shaped sketches of the

		bola kasti field, while one group drew a kite-shaped sketch, with each vertex representing the batter's point and the bases in the game.
Students plot each point displacement from the *bola kasti* game sketch onto a Cartesian coordinate system.	Students transfer the sketch they have created onto a Cartesian coordinate system, using the starting/batter's point as the origin (0,0) and the first, second, and third bases as the translated points.	All groups were able to represent the *bola kasti* game sketch on a Cartesian coordinate system, with displacement points differing according to the step counts and directions recorded in Question 1.
Students identify the relationship between the coordinates of the batter's point (initial point) and the translated points from first base, second base, third base, and back to the batter's point (initial point).	Students identify the changes in values from the initial point (0,0) to the new points (first base, second base, and third base) resulting from the players' displacements.	Four groups were able to identify the changes in values from the initial point (0,0) to the new points, namely the points at each base, which are influenced by the number of steps in each displacement. Rightward or leftward displacements were represented as changes along the x-axis, while forward or backward displacements were represented along the y-axis. These changes result from adding the initial point to the displacement vector. However, the remaining two groups were unable to identify these value changes correctly. For leftward displacements along the x-axis and backward displacements along the y-axis, the students assumed that subtraction should be used, whereas the correct operation is still addition with negative values.
Students conclude their understanding of the concept of translation based on the *bola kasti* game activities.	Students are able to summarize their understanding of the concept of translation based on the *bola kasti* game they have played.	The majority of students were able to conclude that translation is the shift or movement from an initial point to a new point (image), influenced by a specific distance and direction. In the context of the *bola kasti* game, this is represented by the number of steps taken to the right or left, as well as forward or backward. However, some students were unable to fully conclude the concept of translation. These students only stated that translation is a displacement of a point, without explaining that the displacement is determined by the number of steps taken when moving from one point to another.
Students are able to rediscover the concept of translation in a formal representation.	Students can rediscover the concept of translation more abstractly and formally by expressing the displacement of a	Students can rediscover the concept of translation and represent it formally as the displacement of a point (x, y) by a units horizontally and b units vertically. However,

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	point (x, y) by a units horizontally and b units vertically	some students expressed the point displacements verbally and recorded them without using formal symbols on the student activity sheets.

Overall, the learning activities were consistent with the designed HLT. Various student responses and thinking strategies emerged as predicted. One example is the students' ability to identify changes in values from the initial point (0,0) to the new points resulting from displacements. At this stage, some students still experienced confusion in linking point displacements with the number of steps recorded in Question 1. This confusion arose because some students assumed that leftward displacements along the x-axis and backward displacements along the y-axis should involve subtraction, whereas the correct approach is to use addition with negative displacement values.

Another finding during the implementation was that some students were unable to fully conclude the concept of translation from the series of activities undertaken. This occurred because students focused too much on determining the operations used to convert the initial point into the new point (image). As a result, they did not yet understand that leftward horizontal and downward vertical displacements are represented by negative numbers. Therefore, this aspect requires correction so that students can accurately express displacements using negative values.

Furthermore, for the questions aimed at guiding students to rediscover the concept of translation, some students, despite understanding the concept through the bola kasti game activities, were still unable to write it formally using mathematical symbols to represent the displacement of a point. Accordingly, additional reinforcement is needed so that students can express point displacements accurately and formally. The results of the learning implementation are illustrated using an iceberg model, as shown in Figure 12.

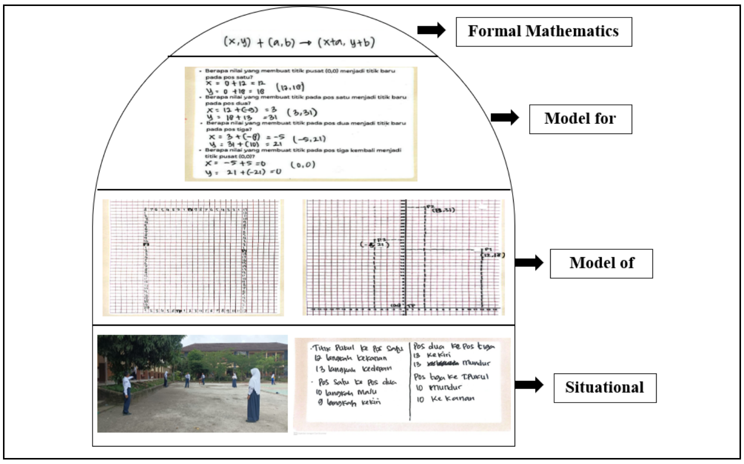

Figure 12. Iceberg Model in Teaching the Concept of Translation

Based on Figure 12 and the results of the comparative analysis between the HLT and ALT, it was found that, overall, the designed HLT successfully assisted students in understanding the concept of translation through the PMRI approach using the context of the bola kasti game. This approach allowed students to build their understanding gradually and deeply, beginning with the situational stage, which starts from real experiences or conditions encountered by students during the bola kasti game. It then progresses to the model of stage, where students begin to construct their understanding informally, moving toward a more formal understanding at the stage model, and ultimately enabling students to express the concept in formal mathematical terms.

Discussion

In designing learning activities on the topic of translation, the researcher first examined various difficulties encountered by students in learning geometric transformations, particularly the concept of translation. In addition, the researcher conducted an in-depth literature review related to the curriculum to analyze learning objectives and relevant activities to achieve those objectives (Nizar & Siregar, 2019). The researcher also reviewed theories on the PMRI approach and the use of contexts that are closely related to students' experiences (Putri et al., 2015; Rosyada et al., 2025). In this study, the traditional bola kasti game was used as a starting point to encourage students to construct their understanding of the concept of translation (Gravemeijer & Cobb, 2006; Nur, 2025; Rusdi et al., 2020) The results obtained at this stage were used to develop the HLT in accordance with the three main principles of PMRI: Guided Reinvention and Progressive Mathematizing, Didactical Phenomenology, and Self-Developed Models (Gravemeijer & Cobb, 2006; Nizar & Siregar, 2019). Subsequently, the designed HLT was trialed during the design experiment stage.

The design experiment stage consisted of two cycles: the pilot experiment as the first cycle and the teaching experiment as the second cycle. Various student responses and thinking strategies emerged during the implementation of learning. In the initial activity, students were first invited to participate in a physical activity in the form of a bola kasti game. After the game, students completed the provided activity sheets. In the first question, students were able to record all displacements from the hitter's point to first, second, and third bases, and back to the hitter's point. The results demonstrated that students could understand the flow of the bola kasti game as a starting point for constructing their understanding of the translation concept. This finding aligns with Rosyada et al. (2025) Who stated that students can analyze contextual problems as a starting point for learning. Moreover, Surgandini et al. (2019) Emphasized that the use of context can make learning more enjoyable, thereby encouraging students to engage actively in the learning process.

Subsequently, in questions two and three, students reconstructed the bola kasti game in the form of sketches on graph paper and Cartesian coordinates. In drawing these sketches, neither the starting point nor the center of the game was predetermined. Students were given the freedom to create sketches according to their understanding of the course of the game. After completing the sketches, students then transferred them onto Cartesian coordinates, designating the hitter's point as the origin (0,0). In representing the displacements within the bola kasti game, students adjusted the positions of points based on the recordings from the first question, resulting in varying displacement coordinates among groups. This freedom was intended to allow students greater opportunity to explore each displacement. This stage aligns with a core principle of PMRI, namely guided reinvention, in which students are given the chance to construct and rediscover mathematical ideas and concepts (Fauziah et al., 2020).

In the fourth question, students were asked to identify the changes in values from the initial point to the new point resulting from the displacement. This stage represents a process of vertical mathematization, in which students begin to transform their understanding from a model of toward a model for, namely a model that progresses toward formal mathematical representation. In previous research, Rosyada et al. (2025) stated that at the model for stage, students were able to represent point translations in a non-formal mathematical form. This finding is consistent with the theory of progressive mathematization proposed by Gravemeijer & Cobb (2006), which defines vertical mathematization as a process that moves from informal

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models toward formal mathematical structures. However, students' responses to this question revealed several findings, particularly errors made when determining horizontal translations to the left and vertical translations downward. Students tended to assume that the operation involved subtraction, without recognizing that the translation values should instead be represented as negative quantities. This finding aligns with Surya et al. (2021) who stated that errors in completing the translation process are caused by insufficient understanding of prerequisite knowledge regarding positive and negative numbers, leading students to misinterpret mathematical symbols, including the operations involved.

In the fifth question, students were asked to conclude their understanding of translation based on the activities they had completed. Their understanding was then generalized in a more abstract manner in the sixth question, which guided students to model the concept of translation in a formal mathematical representation. In this question, students were able to comprehend that translation involves moving a point from its initial position to a new position with a specific direction and distance, and they were able to express the concept of translation in formal mathematical terms. This indicates that students have developed a deep understanding of the concept of translation through the use of the traditional game of rounders.

Based on the results of the retrospective analysis, it was found that, overall, the learning activities were aligned with the designed HLT and contributed positively to the development of the LIT in teaching translation. This alignment occurred because the HLT successfully facilitated students' understanding of the concept of translation through the PMRI approach using the traditional game of rounders, which proved to be effective, practical, and tailored to students' needs (Doorman, 2019; Gravemeijer & Cobb, 2006). This approach allowed students to gradually and deeply construct their understanding, reflecting the core principle of PMRI, namely Guided Reinvention. The process of mathematization followed this, guiding students toward mathematical thinking starting from the situational stage, which arises from students' real experiences during the rounders game, referred to as horizontal mathematization. It then progressed to the "model of" stage, where students begin to construct understanding informally toward a more formal comprehension, known as the "model for," representing vertical mathematization. Additionally, the principle of Self-Developed Models served as a bridge linking contextual understanding to formal mathematics, enabling students to model their understanding and eventually express it in formal mathematical terms (Fauziah et al., 2020; Gravemeijer & Cobb, 2006).

Conclusion

This study developed a learning design in the form of a Hypothetical Learning Trajectory (HLT) on the topic of translation, based on the PMRI approach, using the traditional game of rounders, which can contribute to the development of Local Instruction Theory (LIT) to enhance students' conceptual understanding. The research process consisted of three stages: Preliminary Design, Design Experiment, and Retrospective Analysis. The findings of this study indicate that learning through the *bola kasti* game effectively fosters students' deep understanding of the concept of translation. However, the implementation revealed that some students were not yet able to express the concept of translation symbolically. Several errors were identified, particularly when students determined horizontal movements to the left and vertical movements downward. Students tended to apply subtraction operations without recognizing that such movements should be represented as negative values according to the direction of the translation. Furthermore, this study is limited to students' conceptual understanding of translation and has not yet addressed contextual problem-solving related to the topic. Therefore, future research is recommended to refine and integrate digital-based learning activities that focus on the representation of negative numbers as well as broader contextual problem-solving tasks.

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Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

A.M.M conceptualized the research idea presented, collected the data, organized the data, analyzed the data, and discussed the results. The other three author's (Z., E.S and M.) actively contributed to methodology, Validation, Supervision and approval of the final version of the work. The percentage contributions for the conceptualization, drafting, and revision of this paper are as follows: A.M.M.: 60%, Z.: 15%, E.S.:15% and M.: 10%.

Data Availability Statement

The authors state that the data supporting the findings of this study will be made available by the corresponding author, [Z.], upon reasonable request.

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