Primatika. J. Pend. Mat.
Vol. 14, No. 1, 2025, pp. 167–180

Learning design for translation materials based on Realistic Mathematics Education (RME) principles using the snakes and ladders game

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Abstract

This study aimed to design a learning activity for the concept of translation using the Realistic Mathematics Education approach, incorporating the Snakes and Ladders game context. This context was chosen for its familiarity with students, making it an effective bridge to understanding the abstract concept of translation. This type of research was design research, specifically a validation studies, comprising the stages of preparation, design experimentation, and retrospective analysis. The research sample involved 16 students from Al Fatah Madrasah Aliyah Palembang, Grade XI, with data collected through observation, interviews, and document analysis. The results demonstrated that the context of the Snakes and Ladders game effectively facilitated students' understanding of translation through exploration activities, sketch modelling, and mapping on the Cartesian coordinate plane. Students could identify patterns and formulate the translation rule formally with minimal guidance. This study highlights that integrating game-based contexts within the RME approach can create meaningful learning experiences while enhancing students' comprehension of abstract mathematical concepts.

Keywords: Translation, Realistic Mathematics Education, Design research, Snake and ladders

Abstrak

Penelitian ini bertujuan merancang desain pembelajaran translasi menggunakan pendekatan Pendidikan Matematika Realistik dengan konteks permainan ular tangga. Konteks ini dipilih karena keakrabannya dengan siswa, sehingga mampu menjembatani pemahaman abstrak tentang translasi. Jenis penelitian ini adalah *design research*, secara khusus termasuk dalam *validation studies* yang terdiri dari tahap persiapan, eksperimen desain, dan analisis retrospektif. Sampel penelitian melibatkan 16 siswa Madrasah Aliyah Al Fatah Palembang Kelas XI dengan data yang dikumpulkan melalui observasi, wawancara, dan analisis dokumen. Hasil penelitian menunjukkan bahwa konteks permainan ular tangga efektif dalam membantu siswa memahami konsep translasi melalui aktivitas eksplorasi, pembuatan model sketsa, dan pemetaan pada bidang koordinat Kartesius. Siswa mampu menemukan pola translasi dan merumuskan secara formal dengan bimbingan yang minimal. Penelitian ini menegaskan bahwa integrasi konteks permainan dalam pendekatan RME

dapat menciptakan pembelajaran yang bermakna, sekaligus meningkatkan pemahaman siswa terhadap konsep matematika yang abstrak.

Kata kunci: Translasi, Realistic Mathematics Education, Desain penelitian, Ular tangga

How to Cite: Ramadan, D. C., Susanti, E., Zulkardi, & Meryansumayeka. (2025). Learning design for translation materials based on Realistic Mathematics Education (RME) principles using the snakes and ladders game. *Primatika: Jurnal Pendidikan Matematika*, *14*(1), 167–180. https://doi.org/10.30872/primatika.v14i1.4857

INTRODUCTION

Mathematics is the foundation for various disciplines (Syutaridho et al., 2025). It is a fundamental component of the curriculum that should be provided to all students (Samsinar et al., 2023). Mathematics education should encourage students to actively explore, reflect, and construct knowledge, not just receive facts (Purwati, 2023). This process includes developing critical thinking skills to understand concepts and relationships between concepts, where students are encouraged to gain understanding through experiences with the properties possessed or not possessed by a set of objects (Bhoke, 2020). A topic requiring deep knowledge in mathematics education is geometric transformations (Auliya & Wahyuni, 2024). This study focuses exclusively on the topic of translation. Translation is a topic that discusses the shifting of all points in a figure uniformly in direction and distance (Sutopo & Ratu, 2022).

Students' difficulties often lie in imagining the results of a plane's reflection, rotation, and dilation (Ardinata et al., 2020). These difficulties stem from monotonous teaching methods and the overly abstract nature of the material, making it hard to understand (Nurhayati, 2023). These challenges emphasise the need for more contextual teaching methods that connect mathematical concepts to real-life situations, making them more comprehensible for students. The Realistic Mathematics Education (RME) approach has effectively addressed these issues. RME is an instructional approach in mathematics that originated and was further developed by the Freudenthal Institute in the Netherlands (Da, 2023).

RME aims to enhance students' abilities in critical thinking and mathematical creativity (Palinussa et al., 2021). This approach encourages students to explore, discover, and use mathematics to solve problems individually and in groups (Putri & Zulkardi, 2019). To help students better grasp abstract mathematical concepts, mathematics teachers should implement RME in their classrooms (Laurens et al., 2017). The use of the RME approach can enhance learning outcomes (Fauzi et al., 2021). For example, research conducted by Yuniarti (2022) stated that students' mathematical understanding improves alongside student-constructed results in each RME activity. Further, research by Mufti & Aziz (2024) showed that following the steps of RME can lead to achieving learning objectives. Another study by Lestari et al. (2021) revealed that RME learning designs for translation and reflection topics can help students' conceptual understanding.

One of the main characteristics of RME is the use of real-world contexts. This mindset is due to the idea that the foundation of mathematics is human activities (Juana et al., 2022). In the RME approach, context helps form concepts, motivate learning, build models, and provide tools like procedures, notation, diagrams, and rules (Zulkardi & Putri, 2020). The context used in this research is the Snakes and Ladders game. This game, widely known among students, can be a fun and interactive medium to illustrate systematic movement (translation) on a two-dimensional plane. Through the Snakes and Ladders game context, students can visually and practically understand how translation works, thus gaining better comprehension. The use of game contexts can make learning meaningful, as demonstrated in research by Syutaridho et al. (2023), where using kites as a game context effectively taught number topics to students. Similarly, research by Sari et al. (2019) showed that using the sut-sut game as a starting point for learning produced a learning design that helped students acquire initial knowledge and basic number concepts.

METHODS

This study aimed to design a learning approach using the Realistic Mathematics Education (RME) approach and the Snakes and Ladders game context to facilitate students' understanding of mathematical translation. This type of research was design research, specifically validation studies, which serves as a research paradigm for designing, developing, and evaluating educational interventions to address complex issues in practice (Erviani et al., 2024). The research was conducted at Madrasah Aliyah (MA) Al Fatah Palembang, involving 16 eleventh-grade (Grade XI) students, selected through convenience sampling based on class availability and teacher recommendations.

Data were collected through observation, interviews, and student document analysis. Students selected for interviews were those who showed active participation during group discussions or provided unique responses on their worksheets, aiming to gain deeper insight into their thought processes. Similarly, the student work presented in the figures was chosen because it was representative of the common strategies observed across groups or highlighted insightful approaches. Additionally, the student work displayed was selected based on the variety and differences in how students answered, showcasing diverse ways of thinking.

The process included three main phases: Preliminary Design, Design Experiment, and Retrospective Analysis (Kurnia et al., 2023) with procedures that covered pre-field, field, and overall data analysis.

Preparing The Experiment

This stage involved a literature review, designing a Hypothetical Learning Trajectory (HLT), identifying students' difficulties, and developing a learning design to be implemented. The characteristics of the RME approach guided the design of activities.

The researcher involved peers in the activity design process to provide feedback and suggestions.

Design Experiment

This stage comprised two parts: the pilot experiment and the teaching experiment. The pilot experiment was tested on a small group, while the teaching experiment was conducted with 16 students. Data collection techniques included observations, interviews, and document analysis. Observations focused on students' activities during the lesson and were recorded in descriptive notes. Interviews were analysed by transcribing and presenting the findings descriptively. Student work documents were analysed qualitatively by examining their problem-solving strategies and describing them in detail.

Retrospective Analysis

At this stage, the data obtained from the previous stage were reviewed. All data collected during the pilot and teaching experiments were analysed, and the findings obtained during the learning process were described.

RESULTS AND DISCUSSION

Preparing the Experiment

The researcher designed activities to guide students through a student-centred learning approach, promoting independence in learning and positively impacting their understanding. Self-directed and student-centred learning, tailored to students' needs, could be achieved if the teaching process was guided by a student-centred approach (Qutoshi & Poudel, 2014). The researcher developed a learning activity focusing on translation using the RME approach and the Snakes and Ladders game context. The first step was creating a Hypothetical Learning Trajectory (HLT).

Table 1. Hypothetical Learning Trajectory

Activity	Goals	Conjectures
Understanding the movement of game pieces in Snakes and Ladders	Connecting the movement of game pieces in the Snakes and Ladders game to the concept of translation	▪ Students correctly describe the movement of game pieces ▪ Students describe the movement but make Errors ▪ Students fail to describe the movement
Designing a sketch to illustrate the movement of game pieces	Guiding students to model the movement of game pieces in the snakes and ladders game	▪ Students create a sketch of the game piece's movement ▪ Students fail to create a Sketch
Creating a sketch of the movement on the Cartesian coordinate Plane	Guiding students to model the movement of game pieces on the Cartesian Plane	▪ Students represent the movement on the Cartesian plane ▪ Students fail to represent the movement

Activity	Goals	Conjectures
Identifying translation patterns and formulating Them	Guiding students toward formal understanding by analysing the movement of game pieces on the Cartesian plane	▪ Students document and formulate the movement ▪ Students document the movement but cannot formulate it

Table 1 described the Hypothetical Learning Trajectory, which focused on the transition of students' understanding from gameplay experience to mathematical representation, particularly translation on the coordinate plane. The predictions of students' responses helped teachers prepare appropriate interventions at each stage.

Design Experiment

The HLT developed was tested through a design experiment involving six students and a teaching experiment with 16 students. The researcher implemented the HLT to enhance students' understanding of the concept of translation through the Snakes and Ladders game context.

Pilot experiment

Activity 1: Understanding the movement of game pieces in snakes and ladders

The learning process started with the game of Snakes and Ladders. In the first activity, students were asked to play the game prepared by the teacher. While playing, they were instructed to observe and record the movement of the game pieces. Figure 1 illustrated the game used by the students during the learning process.

Figure 1. Starting point activity

After playing the game, students were asked to provide an example of the movement of the game piece after they had roll the dice. One group of students stated that their group had reached the number 8. Through the conversation between the teacher and the students, an understanding was gained of how the students had arrived at the number 8 and how the game piece had moved to reach that number. Next is a short conversation between the researcher and the students.

Researcher : *What number appeared on the dice for you to reach square 8?*
Student 1 : *The dice showed 5, Sir.*
Researcher : *How did the piece move when you played Snakes and Ladders and rolled a 5?*

Student 1 : *The piece moved five steps to the right, and 1 step up. (While demonstrating the movement)*
Researcher : *Why did it move 1 step up?*
Student 1 : *Because there's a ladder, Sir. (Pointing to the ladder on the Snakes and Ladders board)*
Researcher : *And what about you?*
Student 2 : *Same, Sir. The piece moves five steps to the right, and 1 step up. (Showing the work)*

Based on the conversation, it could be concluded that the student understood how to play the Snakes and Ladders game. The student was also able to explain that the game piece moved five steps to the right and one step upward, and accurately recorded this on the activity sheet. The answer from one of the student groups was shown in Figure 2.

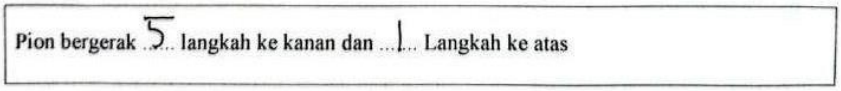
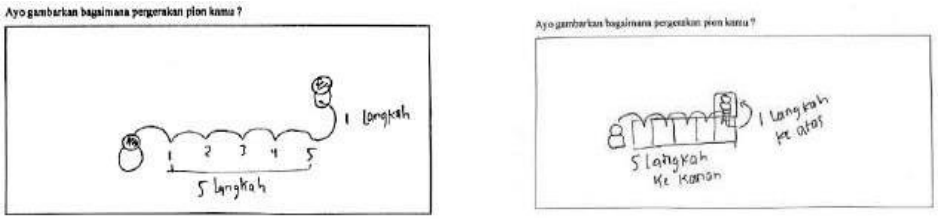


Figure 2. Students' answer results

Activity 2: Designing a sketch to depict the movement of the game piece

In the second activity, students were asked to create sketches depicting the movement of their game pieces. This activity aimed to guide students in representing and modelling the movement of the game pieces in an informal way. Students were free to express this as a model of the game situation and the movements of their playing pieces. Figure 3 showed an example of a model a student wrote on their activity sheet.



(a) (b)

Figure 3. Students' sketch results

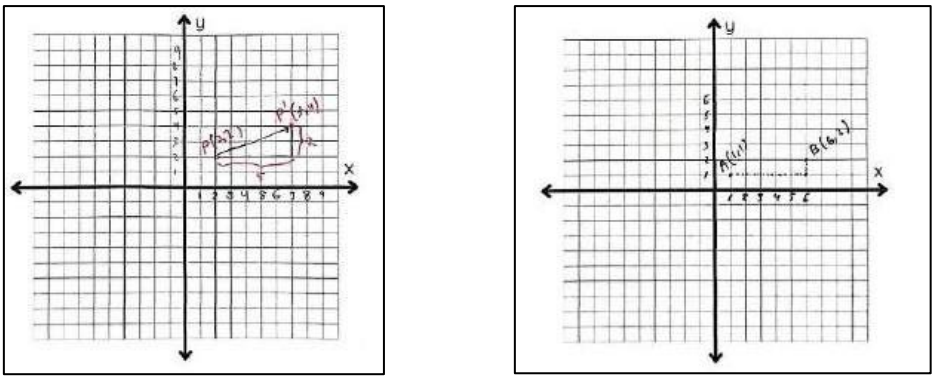
Figure 3 showed that the results from both students produced nearly identical representations of the game piece's movement when a dice roll of 5 was shown. However, to explore the ideas in the students' minds while modeling this situation, the following conversation between the teacher and the students provided clear insight.

Researcher : *How will you draw it?*
Student 1 : *Sir, I will use a number line. (Drawing a number line)*
Student 2 : *I'll draw boxes first, sir, and then indicate the steps. (Drawing boxes and marking steps)*
Researcher : *How does the movement look in your drawing?*
Students : *(Demonstrating the movement while sketching it)*

Based on the interview and the students' responses in Figure 3, they successfully created effective sketches of the game piece's movement, each using a different strategy. The students were able to model model the game piece's movement in a given situation. The difference was that student (a) illustrated it using lines, while student (b) represented it in the form of squares. However, the essence and meaning of both images remained the same.

Activity 3: Sketching the movement of the game piece on the cartesian coordinate plane.

In the third activity, students were asked to create a sketch and apply the movement of the game piece on a Cartesian coordinate plane. This activity aimed to guide and bridge the students from an informal to a formal representation. At this stage, students were instructed to transfer the Snakes and Ladders game situation onto the Cartesian coordinate system, assuming that the movement of each square represented one unit. The answers given by the students can be seen in Figure 4.



(a) (b)

Figure 4. Result sketch student's in the coordinate plane

Figure 4 illustrated that while both students successfully modeled the translation, they chose different starting points. Student (a) depicted the movement from an initial point P(2,2) to a final point P′(7,3). In contrast, student (b) chose a simpler starting point at A(1,1), which translated to the final point B(6,2). Despite these different coordinates, both sketches correctly represented a translation of 5 units to the right and 1 unit up, demonstrating a consistent understanding of the underlying concept.

Researcher : *Please determine the starting position. Where do you set the piece's starting position, and why there?*
Student 1 : *I chose point A with coordinates A(1,1) because it's the easiest.*
Student 2 : *I chose point P with coordinates P(2,2). I just picked it randomly, Sir.*
Researcher : *How did you draw it?*
Student 1 : *Sir, I placed the starting point at A(1,1) and the final position at B(6,2).*
Student 2 : *I placed the starting point at P(2,2), and its final position is Q(7,3), Sir.*
Researcher : *All right, please continue.* Students *: (Continuing the activity)*

Based on the interview and the student's responses in Figure 4, the students successfully modelled the movement of the game piece from the Snakes and Ladders game on the Cartesian coordinate plane. They simulated and represented the game piece as a coordinate point that shifted according to the steps and movement of the piece in the previous activity.

Activity 4: Identifying translation patterns and formulating them

In activity 4, students were asked to identify the pattern of the translation formula by expressing the images they created in mathematical language. In this stage, students were guided to generalise the movement of the game piece on the Cartesian coordinate plane into the concept of translation. The teacher encouraged the students to observe the changes in the x- and y-coordinates from the starting point to the endpoint they had established.

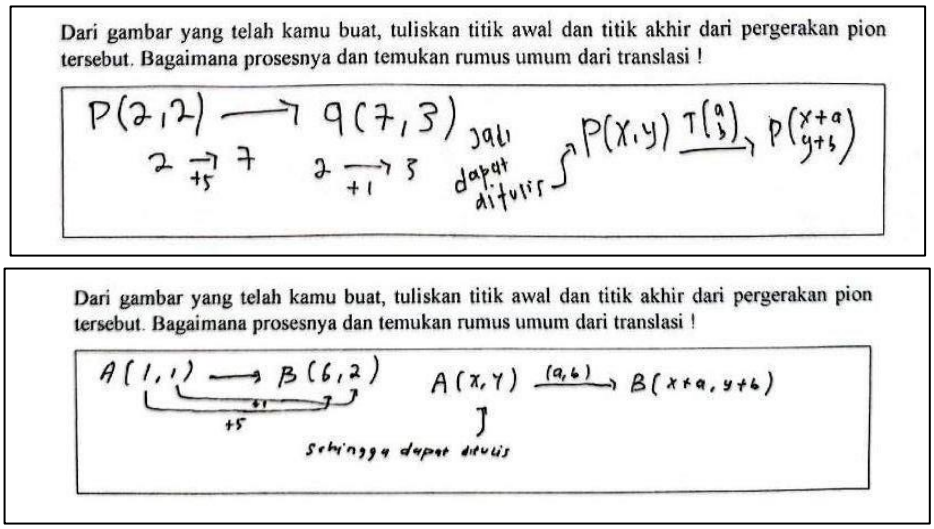


Figure 5. Formal answer results from two students

In Figure 5, both students noticed a change in the abscissa by 5 units and a shift in the ordinate by 1 unit, even though the starting and ending points chosen by the students were not the same. Next, through scaffolding, the students were guided to generalise and express the concept and formula of translation in formal mathematical terms. Below was an example of the teacher's guidance during the scaffolding process.

Researcher : *Is there a pattern from the starting point to the ending point?*
Student 1 : *From point (1,1), it changes to (6,2), Sir. So, x increases by 5, and y increases by 1, Sir.*
Student 2 : *Yes, Sir, the same here. The change is an addition of 5 and 1, like my points P(2,2) to Q(7,3).*
Researcher : *Now, what is the formula for translation?*
Student 1 : *The change can be represented as a and b, so it becomes (x+a, y+b).*
Student 2 : *Oh yes, that's correct, Sir.*

Based on the interview and the student's responses in Figure 5, various strategies were used to generalise the concept into a general form. However, from the students'

answers, it was evident that they approached the task intuitively and inductively, observing patterns in the translation to discover the formal form and the general formula for translation.

Teaching experiment

The same activity sheet used in the pilot experiment was applied without revisions in the teaching experiment phase. At this stage, the activity sheet, which had been aligned with the HLT (Hypothetical Learning Trajectory), was tested on 16 students who were divided into four groups, each consisting of 4 students. The groups were formed heterogeneously by the teacher based on students' prior academic abilities to encourage peer tutoring and diverse discussions.

Activity 1: Understanding the movement of the game piece in the snakes and ladders game

As in the pilot phase, the first activity invited students to play the snakes and ladders game first to understand the movement of the game piece. Then, in this first activity, a scenario and question were created: What would happen if a roll of the dice resulted in a 5, and how would the game piece move? The conversation and Figure 6 below illustrated the students' understanding of playing snakes and ladders.

Researcher : *Do you know how to play Snakes and Ladders?*
Group 1 : *Yes, Sir, we do.*
Researcher : *If you start the game and roll a 5, what happens?*
Group 1 : *The piece moves five steps to the right, Sir, and then climbs 1 step up because there's a ladder.*
Researcher : *What about you?*
Group 3 : *Yes, Sir, the same. When we roll a 5, the piece moves five steps, and 1 step up because there's a ladder.*

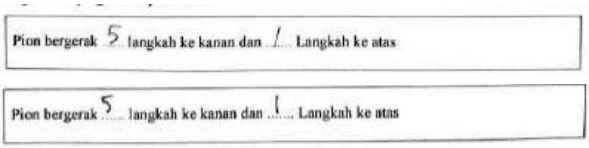


Figure 6. Answer results of group 1 (above) and group 3 (under)

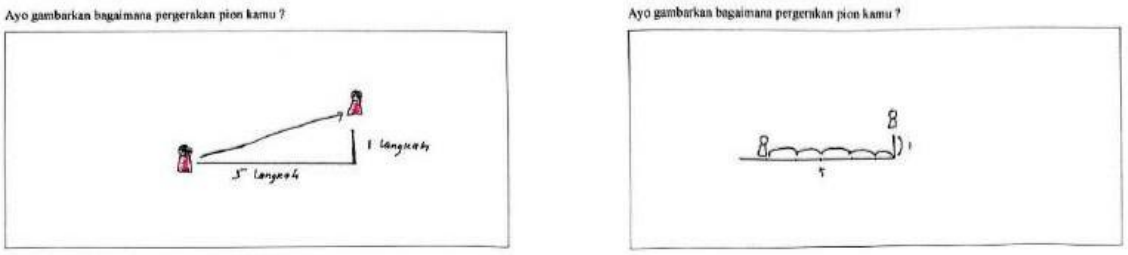
From the interview responses and the students' documents in Figure 6, it was found that all students understood the rules of the Snakes and Ladders game, particularly how to move the game piece. All students answered that if a dice roll resulted in a 5, the game piece would move five steps to the right and 1 step upward.

Activity 2*:* Designing a sketch to depict the movement of the game piece

In activity 2, students were free to sketch the movement of the game piece based on the previous question. Group 2 and group 4 depicted the movement of the game piece accurately. The results of the students' answers could be seen in Figure 7.

In Figure 7, it could be seen that the students successfully sketched the movement of the game piece. Although the answers differed, none were incorrect, as students were free to sketch the movement based on their understanding and

perception. Group 2 drew a line to the right and upward, labelling five steps for the rightward movement and one step for the upward movement. Group 2 also added directional arrows to indicate the change in the position of the game piece, marked in red. However, the strategy used by Group 4 was slightly different. Group 4 used curved lines to represent the jump of five steps to the right and one step upward, indicating the change in the piece's position. Despite these differences, we could conclude that, in general, the students could sketch the movement of the game piece based on the Snakes and Ladders game in an informal mathematical form.

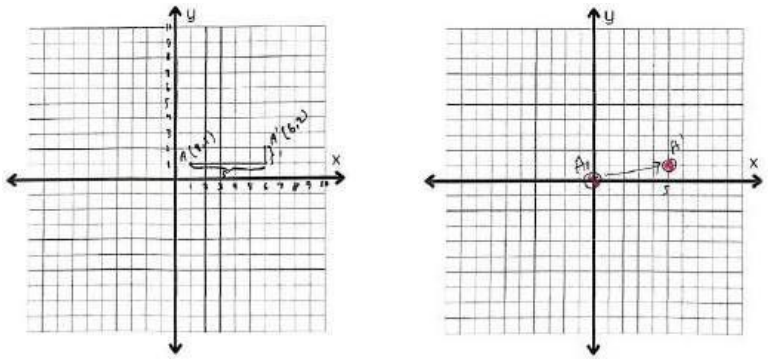


(a) (b)

Figure 7. Sketch results (a) Group 2 and (b) Group 4

Activity 3: Sketching the movement of the game piece on the cartesian coordinate plane

This activity was quite similar to the second activity, with the difference being that in this activity, students were instructed to sketch the movement of the game piece on the Cartesian coordinate plane. First, students were asked to plot points representing the initial and final positions of the game piece on the Cartesian coordinate plane. The sketches made by the students on the coordinate plane can be seen in Figure 8.



(a) (b)

Figure 8. Sketch results on the coordinate plane (a) Group 2 and (b) Group 1

In Figure 8, it could be seen that the students could also depict the initial position of the game piece, the movement pattern, and the final position of the piece. Group 1 placed the initial point at A(0,0) and the final point after the movement at A'(5,1). On the other hand, Group 2 set the initial point at A(1,1) and the final position of the piece at A'(6,2). Although the students identified different initial and final points, the results and the concept of the piece's movement aligned with the predictions made during the pilot experiment stage. This showed that the students could model the game piece's

movement on the coordinate plane effectively.

Activity 4: Identifying translation patterns and formulating them

In activity 4, students identified the translation formula by expressing the images they had created in mathematical language. In this activity, it was observed that Group 1 was still confused about identifying the pattern from what they had created. However, after receiving guidance and hints, they understood it. On the other hand, Group 2 could identify the pattern right away with only a slight prompt from the teacher. Below was the form of guidance provided by the teacher for both Group 1 and Group 2, along with the students' answers from both groups.

Researcher : *What are the coordinates of the starting and ending positions?*
Group 1 : *From the origin (0,0) to (5,1), Sir.*
Group 2 : *We have a point (1,1) moving to (6,2), Sir.*
Researcher : *So, did you find similarities in the results you made? Is there a similar pattern?*
Group 1 : *Not yet, Sir.*
Group 2 : *Yes, Sir, we found that x increases by five and y increases by 1, making it (6,2)*
Researcher : *Group 1, have you found it now?*
Group 1 : *Oh yes, Sir, ours also increases by 5 and 1, making it 0+5 and 0+1, which is (5,1).*

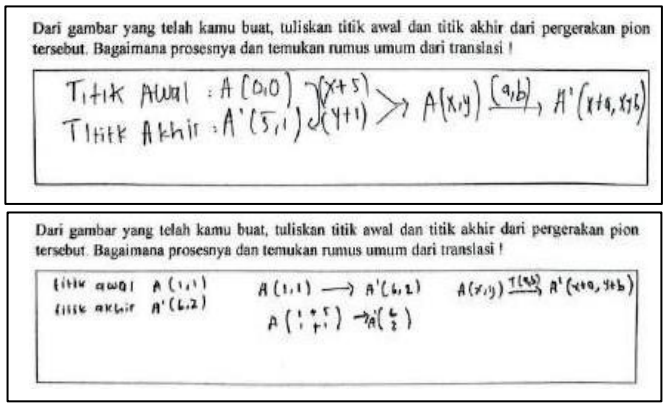


Figure 9. Result response formal of group 1 (above) and group 2 (under)

Based on the interview and the student's responses in Figure 9, it could be concluded that although the points created by the students were different, they used the same pattern to determine the general form and the general formula for translation. It could be seen that both groups of students generalised the concept in the form of $A(x,y) \xrightarrow{T(a,b)} A'(x+a, y+b)$. This expression represented the translation of point $A(x,y)$ by units along the x-axis and b units along the y-axis, resulting in the new point $A'(x+a, y+b)$. The arrow and the notation $\xrightarrow{T(a,b)}$ indicated the direction and magnitude of the translation.

Retrospective Analysis

Several findings were obtained based on the stages of the pilot experiment and the

teaching experiment. First, the learning objectives set were achieved through the designed learning activities. Students could discover the concept of translation from the context of the Snakes and Ladders game. Using the RME approach, various strategies emerged in the students' responses, ranging from the informal model of the model to formal mathematical expressions. This showed that a contextual approach made the learning process meaningful, engaging, and accessible. Through the context of snakes and ladders, students could also recognise and identify patterns and regularities, which ultimately allowed them to determine and generalise these patterns into a general form using their language.

The results of this study were in line with the findings of Fauzi et al. (2021), which showed that the use of the Snakes and Ladders game through the Realistic Mathematics Education (RME) approach had a positive impact on students' understanding of mathematical concepts. This study also supported the findings of Lestari et al. (2021), who stated that a context-based learning design for translation enhanced students' conceptual understanding. Furthermore, these results were consistent with the study by Mufti and Aziz (2024), which concluded that the RME approach was effective in improving students' conceptual understanding of translation material.

CONCLUSION

This study contributed to the development of innovative translation learning designs using the RME approach based on the context of the Snakes and Ladders game. The results showed that this approach helped students understand the concept of translation in-depth through exploration activities, increased student engagement by providing meaningful and relevant learning experiences, and aided students in formulating translation patterns. The implications of this study highlight the importance of using real-life contexts in mathematics education to make abstract concepts easier for students to understand. This research can be expanded by testing the same approach on other geometry transformation topics or with larger groups of students.

We recommend that teachers adopt this game-based HLT as a template. It is crucial to allow students ample time for the initial game-playing phase to build an intuitive foundation before moving to formal coordinates. Teachers should also facilitate discussions around the different sketches created by students, valuing diverse representations as a bridge to formal understanding. This study suggests that integrating familiar, low-cost games like Snakes and Ladders can be an effective national strategy for teaching abstract topics. Curriculum materials could be developed that explicitly include such contextual activities to make mathematics more accessible and engaging for all students.

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