

Design of a Mathematics Game on the Topic of Geometric Transformations Based on Scratch

Ajeng Nur Aulia Fitrianingsih^{1,*}, Rizky Rosjanuardi², Eyus Sudihartini³

^{1,2,3}*Faculty of Mathematics and Science Education Universitas Pendidikan Indonesia, Indonesia*

**email: ajengnaf@upi.edu*

Abstract

The purpose of this research is to describe the development of a Scratch-based mathematics game on geometric transformations. The study followed the Multimedia Development Life Cycle (MDLC), comprising concept, design, material collecting, assembly, testing, and distribution. Thirty-two prospective mathematics teachers at a university in West Java provided feedback through open-ended questionnaires, supported by interviews and documentation. The Super Geo-bros maze game was developed to present translation, rotation, reflection, and dilation. Of the 192 questionnaire responses across six indicators, 186 (96.9%) were coded as positive, representing favorable perceptions of the game rather than evidence of improved learning outcomes. The operation indicator received the lowest proportion of positive responses (27 of 32). Further research should evaluate the game's usability and effectiveness with junior high school students.

Keywords: mathematics game, transformation geometry, Scratch, MDLC.

MSC2020: 97G50, 97U80

Abstrak

Tujuan penelitian ini adalah mendeskripsikan pengembangan game matematika berbasis Scratch pada topik transformasi geometri. Penelitian menggunakan Multimedia Development Life Cycle (MDLC) melalui tahap concept, design, material collecting, assembly, testing, dan distribution. Sebanyak 32 mahasiswa calon guru matematika di salah satu universitas di Jawa Barat memberikan tanggapan melalui angket terbuka, yang didukung wawancara dan dokumentasi. Game Super Geo-bros dikembangkan untuk menyajikan translasi, rotasi, refleksi, dan dilatasi. Dari 192 tanggapan pada enam indikator, sebanyak 186 (96,9%) dikodekan positif. Hasil tersebut menunjukkan penilaian positif responden terhadap game, bukan bukti peningkatan hasil belajar. Indikator pengoperasian memperoleh persentase positif terendah (27 dari 32 responden). Penelitian lanjutan diperlukan untuk menguji kemudahan penggunaan dan efektivitas game pada siswa SMP.

Kata kunci: game matematika, transformasi geometri, Scratch, MDLC.

MSC2020: 97G50, 97U80

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Introduction

Geometric transformation plays a central role in various fields, from mathematics to computer science. It is a branch of geometry that studies how objects or geometric fields undergo changes in position, size, and shape. In the subject of geometric transformation, there are concepts such as translation (shift), rotation (turning), reflection (mirroring), and dilation (enlargement) [1].

In reality, geometric transformation is one of the topics in mathematics that is often considered difficult by many students. According to research, some students are already capable of performing transformations on simple geometric objects, but they encounter difficulties when faced with rotation and reflection problems for more complex figures. Therefore, students need assistance to facilitate learning geometric transformations effectively, such as through learning media.

Scratch-based games offer an interactive way to present geometric transformations. Molina-Ayuso et al. [16] investigated geometry learning through computational-thinking activities using Scratch, while Chasannudin et al. [4] described Scratch training for teachers in computational thinking. Scratch is a visual, block-based programming environment that can be used to create animations and interactive learning projects [3]. It is available through <https://scratch.mit.edu/>. In the present study, Scratch was used to create a geometric-transformation maze game; no improvement in learners' achievement was measured.

Several studies have developed Scratch-based mathematics media on topics such as greatest common divisor (GCD) [2], algebraic multiplication [5], area of a triangle [6], and primary-school geometry [16]. Other applications include physics learning [8] and primary-school science [10], while research on multimedia design for scientific literacy provides related instructional context [9]. These studies indicate a range of uses for educational multimedia; they do not by themselves establish the effectiveness of the game developed in this study.

Recent research provides further context for this development. Molina-Ayuso et al. [16] examined the use of Scratch and computational thinking to support geometry learning among primary-school students. Iskrenovic-Momcilovic [17] reported differences in geometry achievement between learners using Scratch programs and those taught with conventional approaches. Clavinova et al. [18] developed Scratch-assisted project-based learning materials on geometric transformations, with a focus on translation and reflection. Taley et al. [19] investigated factors influencing students' interest in using Scratch for coordinate geometry, including perceived usefulness and usability. Sarifah et al. [20] also found that Scratch-based interactive games supported students' interest in mathematics learning. Although these studies illustrate the potential of Scratch for geometry and mathematics education, their instructional objectives and evaluation methods differ from those of the present work. Therefore, this study aims to describe the MDLC-based design of Super Geo-bros, a maze-style game covering translation, rotation, reflection, and dilation, and to analyze initial responses from prospective mathematics teachers.

Methods

The research design uses the Multimedia Development Life Cycle (MDLC), which has been applied in multimedia application development [7]. According to Luther (1994), MDLC consists of six stages. First, the concept is the stage to determine the objectives and identify the target users of the program. Second, design involves creating the media design in the form of a storyboard. Third, material collecting consists of gathering the materials needed for the game. Fourth, assembly is the process of applying the materials according to the storyboard using Scratch to create the game. Fifth, testing involves repeatedly testing the game's functionality. Sixth, distribution is where the application is

stored on a storage medium. These six stages do not have to be followed in strict sequence; the stages can be interchanged. However, the concept stage must always be completed first. The MDLC diagram can be found in Figure 1 below.

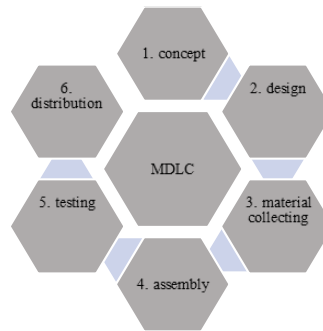


Figure 1. The MDLC Diagram

The topic chosen for this game is the geometric transformation material for 9th-grade junior high school students. The game was designed by a team of four people, consisting of two students and two lecturers, over a period of 10 weeks using the online web-based Scratch application. Subsequently, the game was tested on prospective mathematics teachers at a university in West Java, with 32 student participants. The instrument used in this research was a non-test instrument in the form of an open-ended questionnaire. An open-ended questionnaire consists of questions that can be answered by respondents in descriptive form [11]. The questionnaire used in this study consisted of six open-ended questions related to several indicators, namely display, programming, content [12], language, interest [13], and usefulness. The indicators and open-ended questionnaire questions are shown in Table 1.

Table 1. Questionnaire Indicators

No.	Indicator	Question
1	Display	How is the overall appearance of the game?
2	Program	How does this game operate?
3	Content	How suitable is the content in this game?
4	Language	How is the use of language in this game?
5	Interest	How do you feel after playing the Geo-bros game on the topic of geometric transformations?
6	Usefulness	What is your opinion regarding the usefulness of this game in mathematics learning?

Each of the six open-ended questionnaire responses was coded separately for its corresponding indicator: display, program operation, content suitability, language, interest, or perceived usefulness. A positive code (+) was assigned when the respondent expressed a favorable assessment of that aspect; a negative code (-) was assigned when the respondent expressed an unfavorable assessment or reported a relevant difficulty. For example, difficulties with keyboard controls or internet connectivity were classified as negative for game operation. Thus, one respondent could receive different codes across indicators. The reported data contain one code for each of the six indicators from each of 32 respondents (192 coded responses). Interviews with selected respondents were used to illustrate the questionnaire feedback and were not included as additional entries in the percentage calculation. The percentage of positive responses (PPP) was calculated as follows:

$$PPP = (\text{number of positive coded responses} / \text{total number of coded responses}) \times 100\% \quad (1)$$

For each indicator, PPP uses 32 coded responses; overall PPP uses 192. Table 2 gives the descriptive interpretation categories.

Table 2. The Categorization of Positive Statement Responses

Percentage (%)	Category
$80\% < \text{PPP} \leq 100\%$	Very good
$60\% < \text{PPP} \leq 80\%$	Good
$40\% < \text{PPP} \leq 60\%$	Fairly good
$20\% < \text{PPP} \leq 40\%$	Poor
$0\% \text{ PPP} \leq 20\%$	Very poor

Results and Discussion

The results of this study are as follows:

1. MDLC Process

The design process of the Scratch-based learning media using the Multimedia Development Life Cycle (MDLC) method is as follows:

a. Concept

At this stage, the objectives of the mathematics learning media, which is an enjoyable game, are designed. This learning media can be accessed online through the Scratch application and focuses on geometric transformations for 9th-grade junior high school students.

b. Design

In the planning stage, the initial design of the learning media is created by making a storyboard for the layout of the game to be developed. The storyboard is created using Canva and consists of pages that include the opening screen, introduction screen, menu screen, content display and explanation, practice screen, and game display. The storyboard for the opening screen of the game can be seen in Table 3.

Table 3. Opening Storyboard

Visual	Sketch	Audio
In this frame, there is a screen background with a resolution of 1024x76 px and animation layers.	Title Animation	- Mario Bros Music
	Animation	- Sound Effect
	Explanation	
	Application	
	Opening Message	
	User Identity	

c. Collecting Material

At the collecting stage, the materials needed for the learning media are gathered, including content, images, objects, animations, and sounds. The content on geometric transformations is sourced from an electronic book. The images used as background for the learning media come from Canva templates. The objects and animations are obtained from the Scratch application, and the sounds are sourced from the web.

d. Assembly

At the assembly stage, the game is created according to the model planned in the previous stage. Below are the results of the development of the learning material on geometric transformations using the Scratch application.

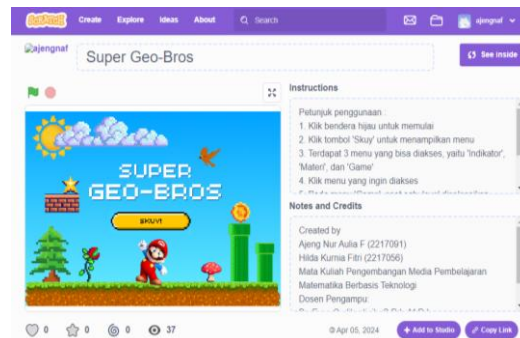


Figure 2. Initial Display

The initial display shown in Figure 2 contains usage instructions and is equipped with a Mario Bros-themed display with a “skuy” button to start the game.

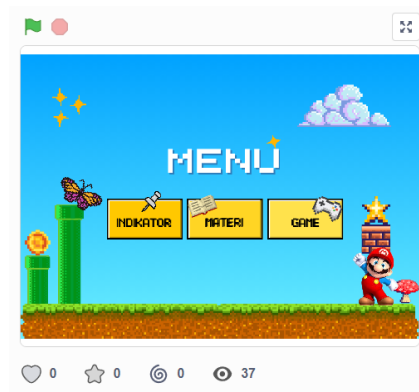


Figure 3. Menu Display

In the menu display shown in Figure 3, there are 3 options that can be freely selected: indicators, material, and game. The material option includes several types of geometric transformations: translation (movement), rotation (turning), reflection (mirroring), and dilation (scale change).

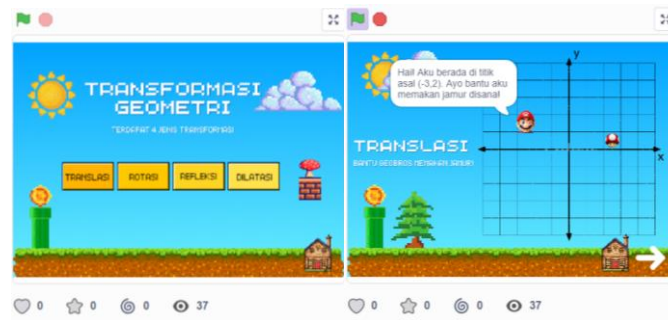


Figure 4. Illustration of Geometric Transformations

Figure 4 presents illustrations of the types of geometric transformations that can be chosen. The illustrations serve as a stimulus for moving on to the material section.

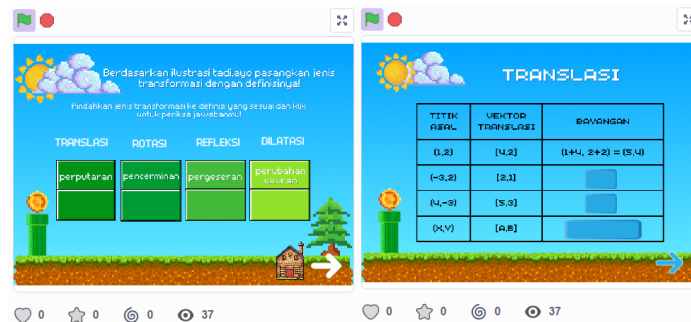


Figure 5. Tables of Geometric Transformations

Figure 5 contains tables of various types of geometric transformations to assist in finding the formulas for these types of transformations.

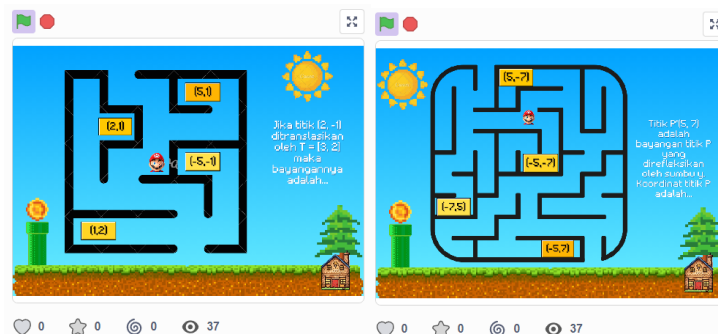


Figure 6. Geometric Transformation Game Display

Figure 6 illustrates the maze-style game, in which students move Mario toward the correct answer to a geometric-transformation question. For example, the displayed task asks for the image of point $(2, -1)$ after translation by vector $T = (3, 2)$. Using $(x, y) \rightarrow (x + 3, y + 2)$, the image is $(2 + 3, -1 + 2) = (5, 1)$. The correct answer, $(5, 1)$, appears as one of the maze choices in Figure 6. This example describes the mathematical task implemented in the game; it does not constitute evidence of learning gains.



Figure 7. Closing Display

Figure 7 shows the closing display when students have played the game by correctly answering all the provided questions.

e. Testing

During the testing stage, the development team checked the content and basic operation of the game weekly and after completing assembly components. These checks were used to identify issues for correction; independent software-performance testing and learning-effectiveness testing were not reported.

f. Distribution

At the distribution stage, the developed game was made available on the Scratch platform for online access.

2. User Acceptance Testing Results

The Scratch-based Super Geo-bros game was developed using the MDLC stages and then reviewed by 32 prospective mathematics teachers through an open-ended questionnaire. Table 4 summarizes the positive (+) and negative (-) codes for each of the six indicators. Across 32 respondents and six indicators, 186 of 192 coded responses were positive, giving an overall proportion of 96.9% ($186/192 \times 100\%$). This value describes responses to the game, not its impact on students' mathematical achievement.

Table 4. User Acceptance Results

Name	How is the overall appearance of the game?	How does the game operate?	How suitable is the material in this game?	How is the use of language in this game?	How do you feel after playing the GeoBros game on the topic of geometric transformations?	What is your opinion on the usefulness of this game in mathematics learning?
R1	+	+	+	+	+	+
R2	+	+	+	+	+	+
R3	+	-	+	+	+	+
R4	+	-	+	+	+	+
R5	+	+	+	+	+	+

Name	How is the overall appearance of the game?	How does the game operate?	How suitable is the material in this game?	How is the use of language in this game?	How do you feel after playing the GeoBros game on the topic of geometric transformations?	What is your opinion on the usefulness of this game in mathematics learning?
R6	+	-	+	+	+	+
R7	+	+	+	+	+	+
R8	+	+	+	+	+	+
R9	+	+	+	+	+	+
R10	-	-	+	+	+	+
R11	+	+	+	+	+	+
R12	+	+	+	+	+	+
R13	+	+	+	+	+	+
R14	+	+	+	+	+	+
R15	+	+	+	+	+	+
R16	+	+	+	+	+	+
R17	+	+	+	+	+	+
R18	+	-	+	+	+	+
R19	+	+	+	+	+	+
R20	+	+	+	+	+	+
R21	+	+	+	+	+	+
R22	+	+	+	+	+	+
R23	+	+	+	+	+	+
R24	+	+	+	+	+	+
R25	+	+	+	+	+	+
R26	+	+	+	+	+	+
R27	+	+	+	+	+	+
R28	+	+	+	+	+	+
R29	+	+	+	+	+	+
R30	+	+	+	+	+	+
R31	+	+	+	+	+	+
R32	+	+	+	+	+	+
Total	31	27	32	32	32	32
Percent age	97%	84%	100%	100%	100%	100%
Category	Very good	Very good	Very good	Very good	Very good	Very good

Based on Table 4, 31 of the 32 respondents expressed positive views of the game's overall appearance. The interview excerpts below describe perceptions of the Mario Bros-themed interface as colorful, visually appealing, and interactive. These are user perceptions rather than independently

assessed measures of interface quality. Other Scratch-based mathematics games have also been developed and evaluated using user feedback [5].

The display indicator received 31 positive responses out of 32 (97% when rounded to the nearest whole percentage point), categorized as very good according to Table 2. The following interview excerpts illustrate the favorable comments about the game's appearance.

A: You mentioned that the overall appearance of the game is very interesting, neat, and good; could you elaborate on that?

R1: Yes, the overall appearance of the game is really eye-catching because the theme is based on Mario Bros. Mario Bros is a game that I have loved since childhood, so I enjoyed playing this.

R2: The game's appearance is quite interesting and interactive, making it very suitable for learning while playing.

R3: The game's appearance is very comfortable and pleasant to look at. Additionally, it is neat and colorful.

The program-operation indicator in Table 4 received 27 positive responses out of 32 (84% when rounded to the nearest whole percentage point), the lowest positive proportion among the six indicators. Five responses were coded negative for this indicator. The interviews below provide examples of both smooth use and difficulties encountered when operating the game.

The comparatively lower assessment of game operation (84%) deserves particular attention. As explained by respondents, playing the game on a mobile phone was difficult because the keyboard arrow controls were not available, while unstable internet connections sometimes interrupted play. This observation is relevant to Taley et al. [19], who identified perceived usability and usefulness as factors associated with students' interest in using Scratch to learn geometry. In addition, the positive responses concerning interest and perceived usefulness are broadly consistent with Sarifah et al. [20], who reported increased interest after using Scratch-based interactive mathematics games. However, the present study assessed the responses of prospective mathematics teachers rather than changes in junior high school students' learning outcomes; therefore, effectiveness in improving geometric transformation achievement remains to be evaluated.

A: You mentioned that the operation of this game runs smoothly but sometimes lags due to signal issues. Additionally, it cannot be operated using a mobile phone because it lacks features that are not available on mobile, such as the up, down, left, and right arrow keys. Could you elaborate on that?

R1: I operated it very smoothly because my signal and device were adequate, so there were no issues.

R2: Since I used my mobile phone, I couldn't play it well, which required me to borrow and take turns with friends. But when I tried it on my friend's laptop, thankfully it worked smoothly.

R3: There were moments of lag due to losing signal.

As shown in Table 4, the indicators of content suitability, language, interest, and perceived usefulness each received 32 positive responses out of 32 (100%). These results indicate unanimously favorable questionnaire responses for those indicators among the participating prospective mathematics teachers. They do not establish content validity, improved motivation, or effectiveness for junior high school students. Selected interview excerpts are presented below.

A: You mentioned that this game is aligned with the material on geometric transformations, the language used is clear, you felt happy while playing, and there are many benefits to this game. Could you elaborate?

R1: The game is very much in line with the material on geometric transformations; all types are conveyed well and clearly without any ambiguous instructions. This game is very beneficial because it keeps students from getting bored while learning.

R2: The designed game is very suitable and very good because students can discover the formulas themselves without needing to be spoon-fed. The questions provided are also good.

R3: All the instructions given are quite clear; while playing, I felt happy because it helped me recall material that I had long forgotten.

For perceived usefulness and language, all 32 respondents were coded as positive (Table 4). The interview excerpts suggest that participants appreciated the game's visual elements, the opportunity to revisit geometric-transformation concepts, and the clarity of its instructions. Prior work has studied Scratch-related learning and problem-solving in other settings [14], but the present study did not test whether this game reduced boredom, improved critical thinking, or increased achievement.

Overall, the findings document the development of a Scratch-based geometric-transformation game and favorable initial feedback from 32 prospective mathematics teachers. The 96.9% overall positive-response proportion reflects questionnaire coding and cannot be interpreted as a learning-effectiveness rate. Previous studies have developed animated mathematics learning materials [12] and other educational games [15], but the present research did not compare the MDLC process with alternative development approaches or assess the game's effectiveness in classroom instruction.

Conclusion

The Super Geo-bros mathematics game was developed in Scratch using the six stages of the Multimedia Development Life Cycle: concept, design, material collecting, assembly, testing, and distribution. The developed game presents translation, rotation, reflection, and dilation through learning materials and maze-style tasks. In the initial evaluation with 32 prospective mathematics teachers, 186 of 192 responses across six questionnaire indicators were positive (96.9%). Program operation received the lowest positive percentage (27/32, approximately 84%), with participants describing difficulties when using mobile devices and encountering unstable internet connections. These results indicate favorable perceptions of the game among the participants, but they do not demonstrate improvements in geometric-transformation learning or establish effectiveness for junior high school students. Further research should test usability across devices and investigate learning outcomes in the intended student population.

Acknowledgments

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