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The effect of block-based game development activities on the geometry achievement, computational thinking skills and opinions of seventh-grade students

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Highlights

- The block-based game development activities are effective in enhancing the achievement
- Block based game development activities positively affected computational thinking skills
- Student views on block-based game development activities based on goal-based scenario learning are positive.

Article Info: Research Article

Keywords: *Block-based game development, Coding, Geometry teaching, Computational thinking, Achievement*

Abstract

The aim of study to investigate the effects of block-based game development activities carried out on the goal-based scenario approach on the geometry achievement and computational thinking skills of seventh-grade students and to reveal their opinions regarding the process. The study used a one-group pretest-posttest experimental model an experimental research design. Overall, 43 seventh-grade students from a district of the province of Van, Turkey, during the 2021–2022 academic year constituted the participants of the study. The participants were determined using the criterion sampling technique a purposeful sampling technique. Within the scope of the study, a goal-based scenario about the topic of polygons was presented to the students, and implementations were carried out. The Computational Thinking Skills Scale, polygons achievement test and a structured interview form were used to collect data. The quantitative data obtained were analyzed using t-test, and the qualitative data were analyzed using content analysis. The results revealed that the block-based game development activities carried

1. Introduction

Computational thinking skill, a 21st-century skill refers to the method of problem-solving (Curzon, 2015; Wing, 2006). Computational thinking, also an analytical thinking style (Wing, 2008), includes actions like logically organizing data and analyzing them, formulizing problems in a way that provides the use of computers or other tools, representing data with models and simulations, determining possible solutions and transforming the generalized solutions to other problem situations (ISTE, 2015). This skill is fundamental for everyone rather than a skill only for those who are interested in computers in a scientific context. Computational thinking skills are accepted as fundamental skills today, just like reading, writing, and mathematics. This skill is "a method or approach of problem-solving, designing systems, and understanding human behaviors benefiting from the fundamental concepts of computer science" (Wing,

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2006, p.33-35). Computational thinking can be thought of as a thinking process in which problems and solutions are represented in a way that information processing techniques are evaluated. It involves solving a calculation problem using logical and algorithmic thinking approaches (Mohaghegh & McCauley, 2016).

Skills such as problem-solving, critical thinking, creativity, and communication appear as skills that every individual should possess within the scope of the 21st century skills (P21). It can be said that coding and programming contents, which have begun to be included in the educational system, are effective ways to gain these skills (Cam & Kiyici, 2022; Nam et al., 2010; Oluk & Korkmaz, 2016). However, in addition to learning coding, using it as a learning tool is considered important in this process. Scratch, which enables block-based coding, is one of the tools that is used for this purpose. (Brown ,2008; Burke & Kafai, 2010; Genç & Karakuş, 2011; Mercan & Aktaş, 2018; Shin & Park, 2014; Vatansever, 2018). Scratch is a block coding software that enables game creation and animation. It is a programming language that appeals to individuals of all ages, mainly those 8–16 (Resnick et al., 2009). It helps not only in learning to program but also in learning other topics and improving the skills of creative thinking, reasoning, and collaboration (Resnick et al., 2009). Learning programming languages is difficult (Jenkins, 2002). Children have difficulties with syntax at early periods; however, coding is made by combining code blocks with Scratch, and can be used without the need for the syntax of the traditional coding languages (Resnick et al., 2009).

Programming also has many advantages in teaching mathematics. In this regard, it contributes to the development of comprehension of concepts such as variables and functions, generalization, and problem-solving skills (Feurzeig et al., 1970). In addition, different studies in the literature used the block coding software, Scratch, in the teaching of various topics of mathematics and geometry, such as probability, algebraic expressions, and polygons and reported positive results (Akpinar & Aslan, 2015; Büyükkarci, 2019; Mercan & Aktaş, 2018; Okuducu, 2020). Moreover, the games and activities built with Scratch made mathematics teaching easier and more enjoyable (Joini et al., 2015; Mercan & Aktaş, 2019).

"Digital competence," one of the eight competence areas in the mathematics curriculum that include the skills students will need in their personal, social, academic, and business lives, includes the use of information and communication technologies (Ministry of National Education [MoNE], 2018). In the 21st century, individuals are expected to be not only consumers but also producers (Kalelioğlu, 2015; MoNE, 2018). In this regard, integrating game development activities into education can be beneficial in preventing the integration of ready-to-use educational tools as consumption as game design activities offer appropriate environments to individuals in terms of combining theory and practice (Kafai ,et al., 1998) and provide both individual and collaborative learning (Robertson & Howells, 2008). The fact that game development processes are experience-based contributes to the discovery of mathematical concepts (Ke, 2014). In a game development process, students can experience abstract mathematical concepts and calculations, such as coordinate place and geometrical shapes. In this process, they can also actively use analytical thinking and reasoning skills (Ke, 2014).

"Constructive perspective," which has recently been accepted and is based on curricula, focuses on students' effort to achieve knowledge as a result of their experience by doing and experiencing rather than delivering the knowledge in a ready-to-use manner. In this regard, one of the constructivist strategies is the goal-based scenario approach. This approach has a similar structure to problem-based learning and collaborative learning (Kandin & Şendurur, 2022). It can help to decrease the abstractness of steps with a solution in a problem-solving process and can facilitate creative learning (Clark & Mayer, 2012; Schank et al., 1999). In this approach, the skills to be gained are integrated into daily life and presented in the context of a goal-based scenario (Schank & Roger, 1996), enabling students to actively participate in the learning process and to create products at the end of the process (Gülbahar et al., 2012). These are the main elements of the goal-based scenario approach: (a) objectives the students need to achieve, (b) the mission that students will pursue, (c) forming needs for the mission and a cover story for explaining these needs, (d) the role and mission that students will play, and (e) the resources that students need to achieve their objectives

(Schank et al.,1999). The literature states that as a result of the applications carried out within the integration of the goal-based scenario approach in the process of game development applications with Scratch, it provides the active participation of the students in the process and provides an enjoyable learning experience for the students (Ceylan, 2020; Kandin, 2019). Therefore, it is thought that the Scratch program is a learning tool that can be used in the goal-based scenario approach.

Software like Scratch, Kodu, Game Maker, and Alice, which enable game development, have positive effects on computational thinking skills (Yünkül et al., 2017). Furthermore, computational thinking skills considered to be related to mathematics (Oluk, 2017; Weintrop et al., 2016) are developed with Scratch, enabling students to improve in terms of mathematical processes such as problem-solving, reasoning, and modeling. (Calao et al., 2015). Studies have shown that Scratch can also be used to design games and has positive effects on teaching mathematical topics (Mercan & Aktaş, 2018).

In the international exam, TIMSS, eighth-grade students are expected to analyze the properties of two- and three-dimensional objects in the learning domain of "Geometric Shapes and Measurements." However, the data from the 2019 TIMSS results revealed that the student's performance in the field of geometry was weak (MoNE, 2020). Similar results were also obtained in the PISA 2018 (MoNE, 2019). Studies conducted with various coding tools showed that coding and game development activities have positive effects on learning mathematics (Hava, 2012; Ke, 2014). Therefore, it is thought that the effect on students' development of educational games using Scratch based on the goal-based scenario approach, which has been used for a long time in mathematics education within the framework of the integration of information and communication technologies with mathematics teaching on teaching geometry, should be investigated. In this direction, the present study aimed to investigate the effects of block-based game development activities carried out on the goal-based scenario approach on the geometry achievement and computational thinking skills of seventh-grade students and to reveal their opinions about the process. For this purpose, an answer was sought to the following questions:

- Is there any significant difference between the pretest and posttest achievement scores of the experimental group students as a result of the block-based game development activities carried out based on the goal-based scenario approach in the topic of polygons?
- Is there any significant difference between the pretest and posttest computational thinking skills and their sub-dimensions (Creativity, Algorithmic Thinking, Collaboration, Critical Thinking, and Problem-Solving) scores of the experimental group students as a result of the block-based game development activities carried out on the goal-based scenario approach in the topic of polygons?
- What are the students' opinions regarding the block-based game development activities carried out based on the goal-based scenario approach in the topic of polygons?

2. Methodology

2.1. Research Model/Design

The study used a one-group pretest-posttest experimental model an experimental research design. Implementation was carried out with a single group in one-group pretest-posttest experimental designs (Büyüköztürk et al., 2020b). This particular research design was preferred for the study as the study investigated the effect of block-based game development activities based on the goal-based scenario approach on the computational thinking skills and achievement scores of the same participant group.

2.2. Data Collecting Tools

This study used the Computational Thinking Skill Scale (CTSS) developed by Korkmaz et al., (2015) to collect data. An Achievement Scale addressing polygons (square, rectangle, parallelogram, and rhombus) was used to determine the participants' geometry achievement. A form titled "I Introduce My Game" developed by the researchers of the present study was used to determine the opinions of the participants regarding the study to obtain some information regarding the games designed by the students and to reveal their opinions about the design process of these games.

CTSS, at the secondary school level, consists of 22 items and five sub-factors: creativity, algorithmic thinking, collaboration, critical thinking, and problem-solving. The items are scaled as: never (1), seldom (2), sometimes (3), usually (4), and always (5). Furthermore, the same includes some negative items (i1, i2, i3, p4, i5, i6), and the grading was reversed for these negative items. As a result of the confirmatory factor analysis of the scale using the maximum likelihood technique, the regression values of the items were found between 0.507 and 0.872. Item test correlation coefficients ranged from 0.655 to 0.862. In addition, internal reliability analyzes were performed on the data to calculate the reliability of the scale. The Cronbach Alpha reliability coefficient was determined as 0.809.

An achievement scale was developed by the researchers of the present study to determine the geometry achievement of the participant students. This scale addressed the polygons (square, rectangle, parallelogram, and rhombus). In the development process of this scale, first, the literature was reviewed, high school entrance exam and secondary school scholarship exams and textbooks were examined, and an open-ended question pool consisting of 14 questions was created. The opinions of two field experts were consulted to measure the target constructs, determine language and clarity, and evaluate the suitability of the topics addressed. In line with their feedback, items found to be unsuitable were excluded from the scale, and a preliminary form of the scale with nine items was obtained. Upon the opinion of an expert, the form of the scale was finalized. The preliminary form of the scale was piloted with ten seventh-grade students who were not among the participants. Since no problem was found regarding the clarity of the questions, the achievement scale was finalized.

A form titled “I Introduce My Game” to obtain information about the aim of the game students designed in the block-based game developing process. (which polygon(s) were used in the game, how to play the game, which characteristics of polygons were intended to be discovered in the game) A structured interview form was also used to reveal the students’ opinions regarding the process. In the development process of the interview form, a literature review was conducted, and five questions were formed. The opinions of two field experts were consulted. In line with their opinions, the interview form was redesigned and piloted with two of the students in the pilot study. The results showed no problems regarding the clarity of the questions; therefore, the form was finalized. The form was implemented for the students in the experimental group for 40 minutes. The form aimed to show the block-based game development process and to reveal their emotions and opinions regarding this process. It also aimed to determine the points that challenged the students in this process and to reveal their opinions regarding the use of this method in mathematics education.

2.3. Participant

Participants were determined using the criterion sampling technique a purposeful sampling technique. This particular technique is used in studies that intend to include working units with certain characteristics (Büyüköztürk et al., 2020b). These criteria were set to determine the participating school: having an informatics classroom, having working computers in the classroom, and having a well-functioning internet infrastructure. These criteria were considered to determine the seventh-grade students to be included in the study: taking and succeeding in the information technologies course in previous grade levels and making some applications using the block-based programming tool, Scratch. Considering all these criteria, a total of 43 seventh-grade students (60.46% female and 39.54% male) from a district of the province of Van, Turkey, during the 2021–2022 academic year constituted the participants of the study. The participating school affiliated with the Ministry of the National Education (MoNE) had fiber internet infrastructure and 15 working order computers. Moreover, these students were included in the study as they attended an information technologies course, carried out some applications using the Scratch programming software, and, therefore, were familiar with block coding.

2.4. Data Analysis

The student's responses to the achievement scale, which was applied to determine the students' achievement on the topic of polygons, were graded with one point for each correct answer and zero points for each incorrect answer. Their overall score was calculated out of 100. The categorization was made in CTSS, a five-point Likert-type scale: scores between 1 and 2.33 were low, scores between 2.34 and 3.66 were moderate, and scores between 3.67 and 5 were high.

The analysis of the standardized scores obtained from CTSS and the achievement scale was made using the SPSS 24 package software. Parametric tests are used when the data display a normal distribution; otherwise, non-parametric tests are used (Büyüköztürk, 2020a). In this regard, the normality of the data distribution was investigated using kurtosis and skewness values. The skewness and kurtosis values of CTSS and its sub-dimensions and the achievement scale are presented in Table 1.

Table 1.
Skewness and kurtosis values of the scores obtained from CTSS and its sub-dimensions, and Achievement Scale

	Skewness	Kurtosis
Achievement Scale	.282	-.100
	.425	-.380
CTSS	.282	-.100
	.425	-.380
Creativity	-.327	-1.130
	-.179	-1.336
Algorithmic Thinking	-.367	-.402
	.012	-.798
Collaboration	-.786	-.001
	-.452	-.834
Critical Thinking	.025	-1.014
	-.172	-.557
Problem Solving	-.040	-.323
	-.190	-.111

The results showed that the present study data showed normal distribution. Therefore, the pretest and posttest mean scores obtained from CTSS and the achievement scale were compared using the related samples t-test, a parametric test (Tabachnick & Fidell, 2013).

The students' opinions regarding the game development process within the scope of the block-based game development activities were analyzed using content analysis. The data obtained were coded by the researchers of the present study at different times and the themes were created. Later, the codes and themes created separately were discussed by the researchers in a meeting. In this meeting, an attempt was made to reach an agreement regarding the different coding. Opinions of the experts were consulted to determine whether or not the themes obtained accurately express the codes. To determines the inter-coder reliability, the formulae (Reliability = Agreement / (Agreement + Disagreement) * 100) suggested by Miles and Huberman (1994) were benefited and the reliability was found to be 92%. To ensure inter-coder reliability, this value is expected to be at least .80 (Miles & Huberman, 1994). Therefore, the value obtained for the present study inferred that the inter-coder reliability was reached.

Internal validity refers to the ability to explain the variance in dependent variables with independent variables (Büyüköztürk et al., 2020b). The experimental study was completed within four weeks to ensure the internal validity of the study because in time different variables other than the independent variables are thought to appear and control the variance in the dependent variables. Before the experimental implementation, the pretest scales were applied to the participants. While applying these tests, the climate was prevented from being stimulant and motivating as much as possible. Course teachers, who were familiar with the students, made the implementations in the process of data collection and carrying out the study.

2.5. Implementation Process

The block-based game development activities made within the scope of the study were based on the goal-based scenario approach. In this approach, target skills are integrated into an authentic situation and presented in a scenario intended for the target set (Schank & Roger, 1996). Figure 1 depicts the steps of scenario-based learning and the implementations carried out by the present study regarding these steps.

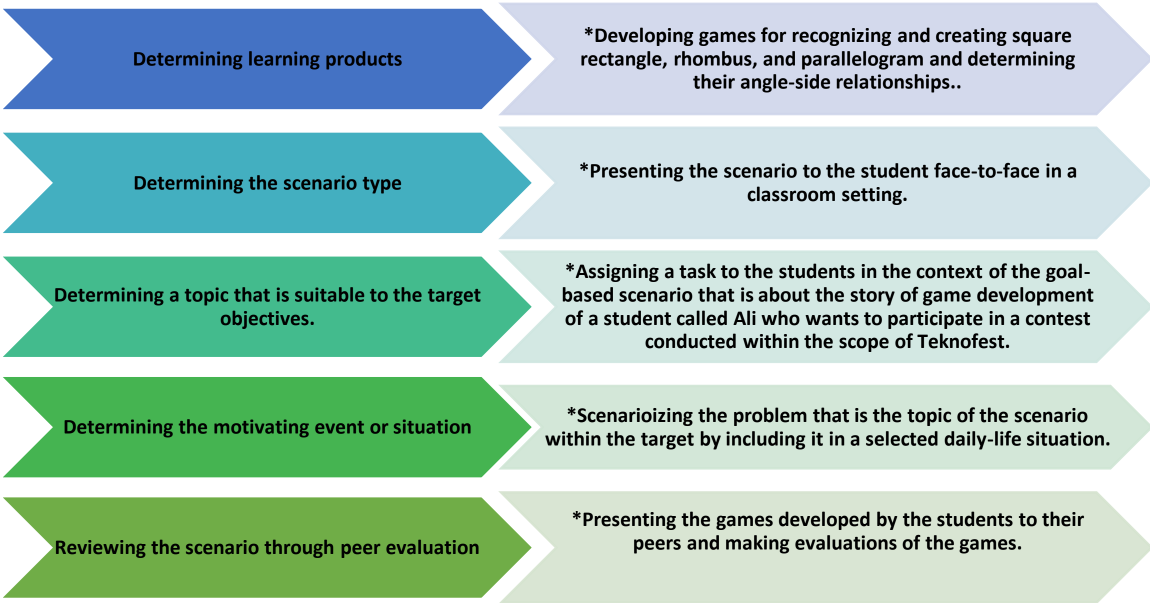

Fig. 1. Steps of goal-based scenario learning and the implementations carried out by the present study regarding these steps

In the goal-based scenario approach, objectives to be included and the way the scenario is presented to students are first determined. In this regard, the objectives included in the scenario were:

- recognizing and creating squares, rectangles, rhombus, and parallelogram;
- determining their interior and exterior angle properties;
- calculating their interior and exterior angles; and
- determining the side and diagonal properties.

The targets set were to include at least one square, rectangle, rhombus, and parallelogram in the game, to use the polygon(s) in the game in an appropriate way in line with the objectives of recognizing, and to create the polygon and discover the angle-side relationships. Furthermore, it is of critical importance to build the scenario with events that might be encountered in daily life. The present study determined a daily life topic and presented this problem in the following scenario:

"Students want to participate in a contest made within the scope of Teknofest (aviation, space, and technology fest.) To that end, they take part in a project that combines robotics coding and mathematics and enables its participants to create their products. In the project, the participants are asked to develop educational games that help to understand the angle-side relationships of polygons (squares, rectangles, rhombus, and parallelograms) using their angle-side characteristics. Ali, who is voluntarily participating in the project, needs to design a game. You can also form your team in this project and help Ali in designing that game. To help Ali, you need to discover the angle-side characteristics of the aforementioned polygons, use these characteristics in your coding, and design games that enable the players to investigate and discover these characteristics."

The scenario was presented to the students face-to-face in a classroom setting. In the next step, determining the motivating event or situation, the problem was integrated into a scenario within the context of a daily life event. Therefore, it was aimed to make the process more meaningful to the students and to ensure their active participation. The process was completed by presenting the games developed to the other students and exchanging opinions.

The purpose of the study was explained to the students at the beginning of the study, and CTSS and the Achievement Scale were given to the students as the pretest. In the experimental stage, the students were asked to design games for exploring polygons (square, rectangle, parallelogram, and rhombus) using the Scratch software within the block-based game developing activities based on goal-based scenario learning. At this stage, information regarding the purpose of the game designed, how to play it, which polygon(s) are included in the game, and which properties of these polygons are intended to be explored in the game were obtained using the form, "I Introduce My Game," which was developed by the researchers of the present study. Within the scope of the "Geometry and Measurement and Evaluation" learning domain in the secondary school mathematics curriculum, the seventh-grade curriculum includes objectives of recognizing rectangles, parallelograms, trapezoids, and rhombus and determining their angle properties based on the previous objectives, such as the main elements of at the fifth-grade level and the parallelograms at the sixth-grade level. The implementations carried out in this study were addressed considering these objective levels. Before the implementations, some remainder questions were posed to the students regarding the polygon types the students had learned in the fifth grade. Later, the scenario and the following seven stages were presented to the students (Schank et al., 1999):

Stage 1 (Objectives): Recognizing and creating parallelograms, rhombus, squares, and rectangles and their angle-side properties, which was expected from the students within the scope of the objectives identified, was determined as the content knowledge and developing educational games for teaching these polygons using this content knowledge was determined the purpose of using the information in the implementation process.

Stage 2 (Mission): The students were given "Ali's Problem." The problem is thought to be motivating and realistic in terms of both its content and includes a contest that is possible for students to participate in at the secondary level.

Stage 3 (Story): For the solution to the problem presented in the given mission, the students are expected to use various strategies, such as trial and error, to understand the problem. The process of selecting a strategy, using the strategy in the mission, and creating a basis for the solution of the problem was used.

Stage 4 (Role): In the given problem, the students were expected to play the role of a software designer who develops an educational game. In this context, guides were given to the students regarding what was expected of them regarding the problem presented.

Stage 5 (Scenario operations): What was expected of the students was explained in terms of the mission and objectives.

Stage 6 (Resources): Since the students' knowledge of polygons from the fifth- and sixth grades differ, the information and resources needed for the games they want to develop will also vary. In this regard, digital resources were obtained from Education Informatics Network (EIN) and given online to the whole classroom. These resources were specifically selected as the internet for using this platform was provided to the students free of charge, and it was easy to transfer the content of the platform to each student. Therefore, the students were given well-organized and easily accessible resources.

Stage 7 (Feedback): The students were given feedback regarding their attainment level of the objectives set in the in-class peer evaluation process regarding the games they developed and their level of success in the mission.

The implementation stages regarding the steps given are presented in Figure 2

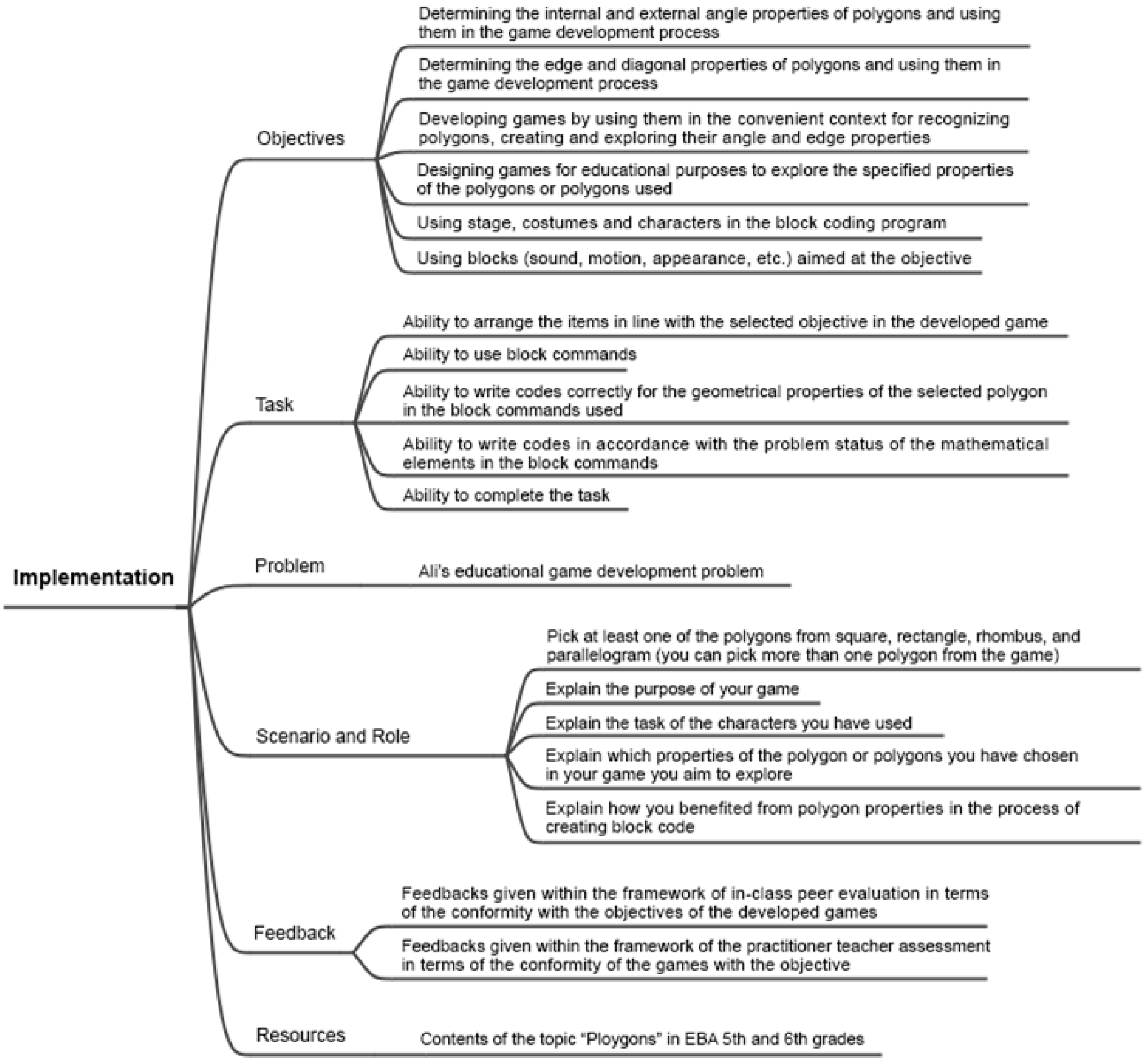

Fig. 2. Implementation Stages

Examples of the games students developed regarding the implementation carried out are presented in Figure 3 and Figure 4.

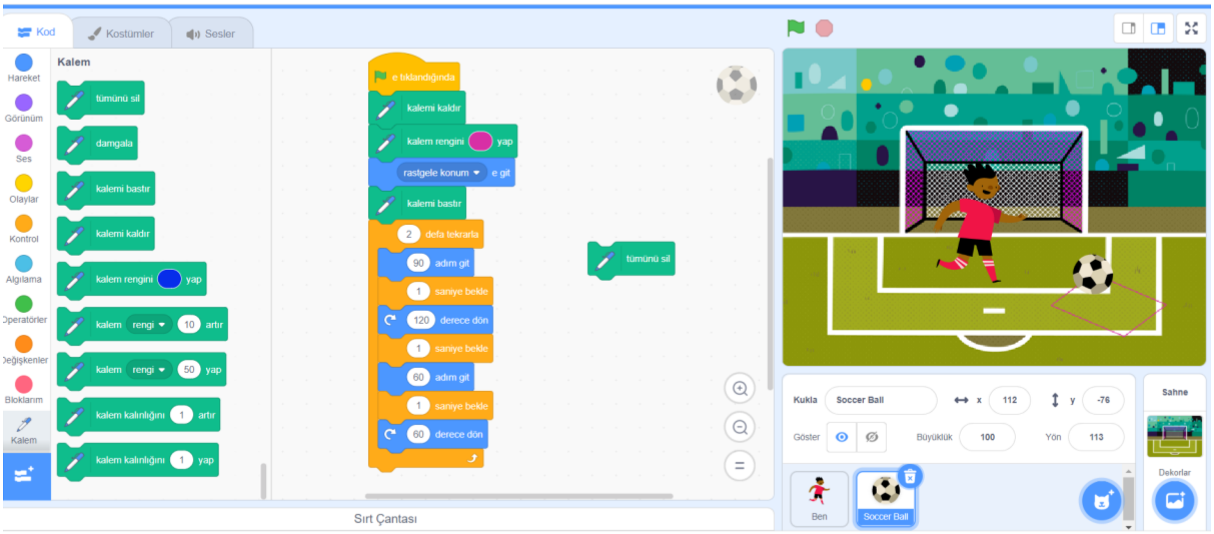

Fig. 3. A screenshot of the game titled "Scoring a goal"

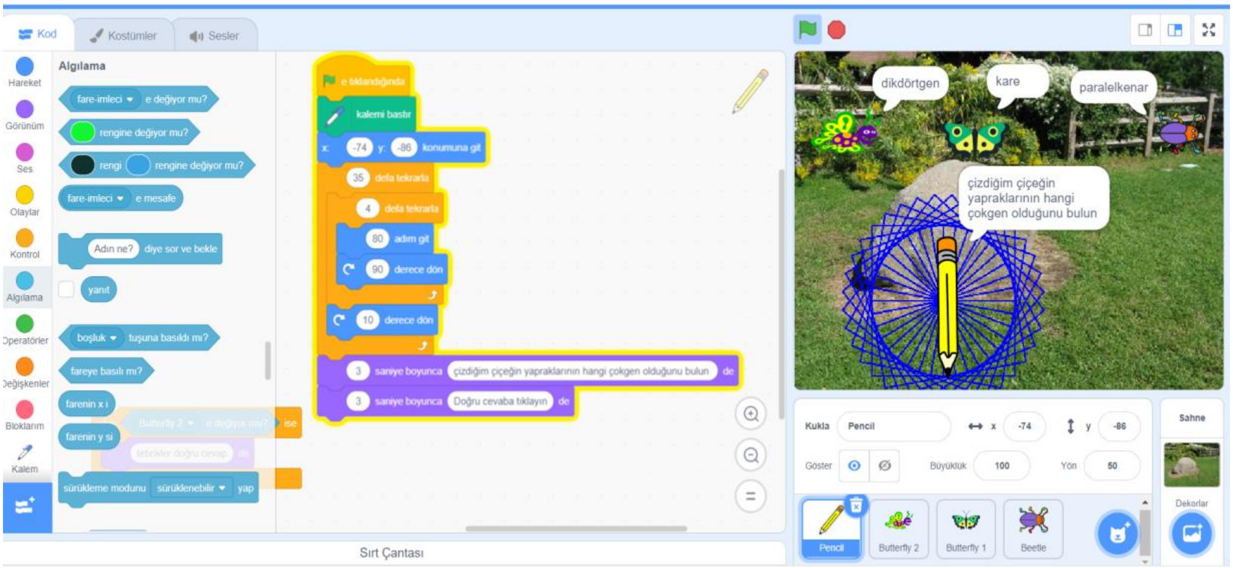

Fig. 4. A screenshot of the game titled "Guess which polygon"

3. Findings

In Findings Regarding the First Research Problem

Within the first research problem, the comparison of the students' mean scores on the pretest and posttest scores in the achievement test applied before and after the implementation based on the block-based game developing activities on the topic of polygons was made using the related samples t-test. The results obtained are presented in Table 2.

Table 2.

Results regarding the comparison of the pretest and posttest scores of the achievement scale using a t-test

Scales		**N**	$\bar{X}$	**SS**	**p**
Achievement Scale	Pretest	43	3.36	0.43	.000*
	Posttest	43	4.54	0.48	

(p<.05)

The results obtained in Table 2 show that there is a .18 difference between the pretest mean score ($\bar{X}$=3.36) and the posttest mean score ($\bar{X}$=3.54) in the achievement scale in favor of the posttest. The t-test results indicate that this difference was significant ($p<.05$). These results can infer that block-based game development activities are effective in enhancing students' achievement.

Findings Regarding the Second Research Problem

Within the first and second research problems, the significance of the experimental group students' pretest and posttest scores in CTSS and its sub-dimensions regarding the block-based game developing activities on the topic of polygons was tested using the related samples t-test, and the results are presented in Table 3.

Table 3.

T-test results of CTSS and its sub-dimensions

	N	$\bar{X}$	SS	P
CTSS	43	1.46	9.59	.000*
	43	1.68	11.07	
Creativity	43	3.93	15.66	.316
	43	4.02	15.71	
Algorithmic Thinking	43	3.49	15.73	.861
	43	3.51	14.73	
Collaboration	43	3.54	21.13	.043*
	43	3.82	17.67	
Critical thinking	43	3.44	16.60	.000*
	43	3.54	15.31	
Problem-solving	43	2.72	15.20	.020*
	43	3.05	17.72	

($p<.05$)

The t-test results of CTSS and its sub-dimensions show that there is a significant difference between the scores before and after the implementation in favor of the posttest scores in the overall CTSS mean score and the collaboration, critical thinking, and problem-solving sub-dimensions. The pretest and posttest mean scores were at a moderate level in the algorithmic thinking, critical thinking, and problem-solving sub-dimensions of CTSS; at a high level in the creativity sub-dimension, and the pretest mean score at moderate, and posttest mean score at a high level in the collaboration sub-dimension.

The results reveal that the implementations significantly affected the mean scores of the collaboration, critical thinking, and problem-solving sub-dimensions of the computational thinking skills. To enhance the creativity, algorithmic thinking, collaboration, critical thinking, and problem-solving sub-dimensions of CTSS, it is thought to be effective in carrying out long-term studies in which mathematics teaching is gamified and integrated with block-coding activities.

Findings Regarding the Third Research Problem

The opinions of the secondary school seventh-grade students regarding the block-based game developing activities on the topic of polygons were analyzed using content analysis, and the results obtained are presented in Table 4.

Table 4.

Descriptive analysis regarding the students' opinions about the implementation

		f	%
Categories	Entertainment	72	56.25
	Beneficial	34	26,56
	Challenge	22	17.19
Total		128	100

As seen in Table 4, three categories were obtained from the students' responses to the questions posed to determine their opinions on the implementation, challenges encountered in the implementation, and making similar applications in mathematics courses. Data about these categories and codes are depicted in Figure 4.

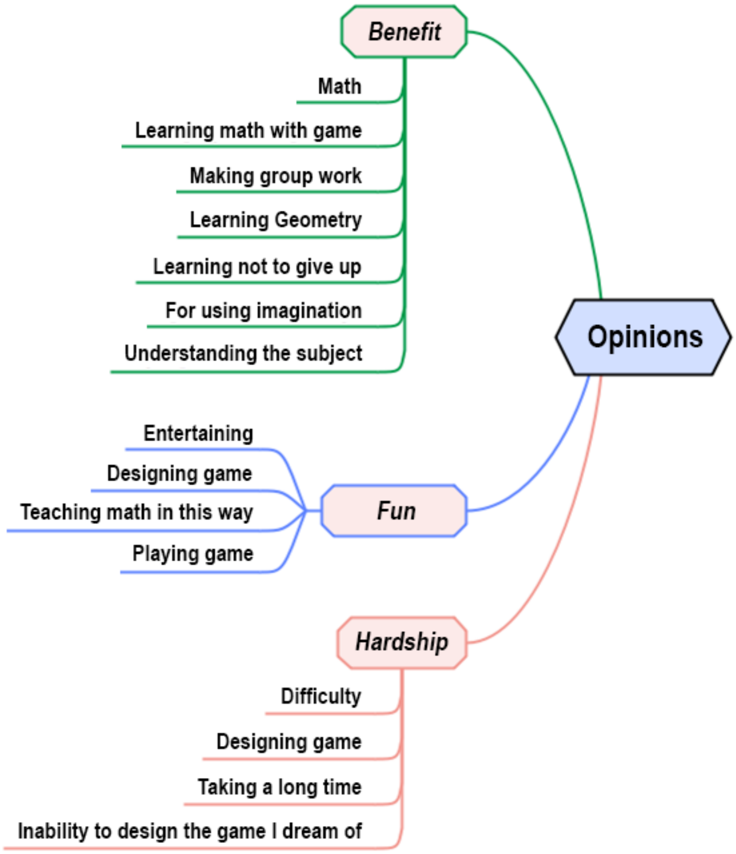

Fig. 5. Codes of the categories obtained from the students' opinions

As seen in Figure 5, the students' opinions were collected under the categories of "Entertainment," "Beneficial," and "Challenge." Under the entertainment category, it was seen that the students found the implementation entertaining, designing a game both entertaining and exciting, making mathematics lessons like this, and playing games entertaining. The students found that learning mathematics through playing games, group studies, learning geometry, learning how to stand firm, using imagination, and the block-based game development activities all helped to understand the topic of polygons. Under the challenge category, some of the students indicated that they had some difficulties since the process was long and they were unable to design the game they had planned. Excerpts of the students' opinions regarding the codes indicated are as follows:

S15: I had fun while playing the game. I had some difficulties while designing the game, but I made a swimming girl while using the codes and had great fun.

S8: Making my character a square and using it on the computer was so beautiful and entertaining.

S7: It was a very challenging process. I had some difficulties while designing the game but managed it. Using my imagination was super beneficial for me, and I would like to learn like this again.

The students' opinions were positive regarding the implementation made and found the process useful and entertaining. It was also detected that the challenge category constituted 17.19% of all opinions.

4. Discussion, Conclusion and Suggestions

When the study's findings were investigated, it was found that the block-based game development activities regarding the topic of polygons are effective in enhancing the achievement of seventh-grade students. This finding was similar to the results of the other studies made by El-Nasr & Smith (2006), Hava (2012), and Ke (2014). The study conducted by Hava (2012) found positive changes in the academic achievement of fourth-grade students who designed games regarding the fraction unit. A different study by El-nasr & Smith (2006) investigated the game development process of 35 undergraduate students and reported that such as process is effective in learning three-dimensional geometry such as vectors.

Game design and development activities and implementations conducted in this regard enable one to increase their mathematical knowledge (Ke, 2014). In this study, the students discovered the properties of squares, rectangles, rhombus, and parallelograms in the block window and integrated these polygons with appropriate codes using the properties. In the game design process, the students were observed coding using mathematical calculations, and the properties of the polygons indicated. The finished process contributed to the students' learning by discovery with trial-and-error in a computer environment.

Another finding obtained by this study was that block-based game development activities positively affected the students' computational thinking skills. Similarly, a study by Fadjo (2012) reported that the computational thinking skills of the students who designed games with the Scratch software were positively affected. Other studies were encountered in the literature asserting the computational thinking skills of the students who created applications with Scratch (e.g., Brennan & Resnick, 2012; Yünkül et al., 2017). However, a different study by Atman Uslu et al. (2018) found no significant change. It was stated that computational thinking skills and mathematics achievement are related (Oluk, 2017). Therefore, it is thought that the increase in the students achievement in the topic of polygons can also stem from this situation.

The findings of the present study also showed an increase in the problem-solving, collaboration, and critical thinking sub-dimensions of CTSS for the students who participated in the block-based game development activities. From this, it can be interpreted that block-based game development activities using Scratch contribute to problem-solving, collaboration, and critical thinking skills. This finding was corroborated by the studies conducted by Vatansever (2018), Akcaoglu & Koehler (2014), and Çubukluöz (2019). A study conducted by Vatansever (2018) reported that the computational skills of secondary school students who designed games with the Scratch software within the scope of the information technologies and software course were enhanced. Akcaoglu & Koehler (2014), in their study, observed an increase in the problem-solving skills of the students who participated in a game design process. A different study by Çubukluöz (2019) concluded that game design processes with Scratch contribute to the improvement of the mathematical problem-solving processes. Moreover, Shin & Park (2014), Nam et al. (2010), and Brown et al. (2008) stated in their studies that the Scratch software develops students' problem-solving skills. On the other hand, Kalelioğlu & Gülbahar (2014) investigated the effect of the Scratch software on students' problem-solving skills and, unlike the aforementioned results, found that there the Scratch software leads to no significant change in students' problem-solving skills. They, however, added that this result might stem from the fact that the implementation process was short. Furthermore, in parallel to the finding of the present study that the students made progress in the critical thinking sub-dimension, Kandin (2019) concluded that using goal-based scenarios in game development activities improves students' critical thinking skills.

Considering the students' opinions regarding block-based game development activities based on goal-based scenario learning, most of the students found the process entertaining. They indicated that designing games, playing them, and learning mathematics in this way were entertaining. Also, they thought the process was useful in terms of learning mathematics through developing games and making group studies. Çubukluöz (2019) and Hava (2012) also found similar results. In a study by Çubukluöz (2019), students' opinions were obtained regarding game design processes made with the Scratch software to eliminate the learning difficulties experienced in a mathematics course. They reported that students find designing games enjoyable and that it helps them to understand mathematics and comprehend mathematical knowledge. Hava (2012) similarly stated that students expressed that they like designing games. Moreover, Kandin (2019) determined that game development activities that adapt the goal-based scenario learning approach offer students entertaining learning experiences.

Some of the students expressed that they had difficulties in the game development process, according to another finding of the present study. This is corroborated by the finding of Çubukluöz (2019), reporting that students had some difficulties while designing games with the Scratch software. In addition, the students' opinions also showed that the students helped each other during the game development process. Parallel to this, Hava (2012) stated that the students exchanged ideas while designing games and interacted with each other, which could lead to the student's improvement in the collaboration sub-dimension.

In the present study, block-based game development activities based on goal-based scenario learning were carried out for the topic of polygons for seventh graders. Studies of game developing activities in the literature were conducted on the topics of mathematics and geometry, such as "Fractions," "Probability," "Algebraic Expressions," and "Polygons (triangles, squares, and rectangles)" (Akpinar & Aslan, 2015; Büyükkarci, 2019; Hava, 2012; Mercan & Aktaş, 2018; Okuducu, 2020). However, it is striking that the content scope of these studies is limited. The effect of block-based game development activities in different topics of mathematics and geometry on educational processes and the outcomes obtained at the end of these processes is not clear. Therefore, it is suggested to conduct further studies on different mathematics and geometry topics using different coding techniques to gain more comprehensive data about the use of block-based game developing activities for teaching different geometry and mathematics. The present study was carried out with seventh-grade students using Scratch, a block-coding software, as the students were familiar with this program. The study can be repeated with additional grade levels and with other coding languages and software, such as C, and C++, which require more comprehensive knowledge. Scratch enables the design of two-dimensional games. Future studies can use different block-coding tools like Kodu Game Lab, which enables the design of three-dimensional games that are more suitable for real-life situations.

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