DESIGN AND DEVELOPMENT OF AN EDUCATIONAL DIGITAL GAME BASED ON MATHEMATICS COURSE TRANSFORMATION GEOMETRY

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Abstract: The digital gaming industry is growing rapidly both economically and in terms of the masses it is influencing. This growth in the sector makes digital games effective in culture and education. In order to use this effect in a beneficial way, it is necessary to be included in the sector. In this research, 8th grade mathematics curriculum a game called "Simetri" has been developed for the purpose of reinforcing the acquisitions of the transformation Geometry subject. The works and processes performed during the development are discussed in this article. The basic structure of the game; it is based on the process of automatically generating the image after the correct clicking of the corners of the image which will result from the reflection of the polygons drawn on the squared paper, dot paper and the coordinate plane with respect to the determined axis of symmetry. There are different difficulty stages within the game and separate levels within these stages. There is also a scoring system in the game and new records are kept. Although the game is mainly based on the concept of reflection, it is open to further development of the concept of translation and the solution of more complex problems.

Keywords: Educational digital games, game development, math games, transformation geometry.

1. Introduction

Although computer games are defined in different ways in different sources, they can be defined as "games play in the electronic environment". When the classification of computer games is considered, the classifications are made according to the type of games, the electronic environment in which they are played and the way they are played. According to the types; action, adventure, fighting, puzzle, role-playing, simulation, sports and strategy games [1], according to the electronic environment; A current classification can be mentioned in the form of PC, web browser, game console, tablet and smartphone games [2].

According to Prensky games; contain rules and objectives, including representation, story, interaction, conflict, competition, challenge, opposition, reputation and problem solving, it is a form of entertainment and role-playing, with activities, adaptations, results and feedback, requiring active participation [1]. Looking at the features, it is understood that digital games will be educational even if they only provide these features. However, it is a fact that this educational role may shift towards negative aspects if it is not controlled by certain mechanisms and its boundaries are not drawn. The fact that entertainment begins to form life itself and the role of the game in real life can be counted as a few issues to be taken precaution on.

Even though the digital gaming sector is still a new sector, it is growing rapidly thanks to technological developments and the possibility to make online purchases. According to Newzoo's 2018 report, this size reached 137.9 billion USD [2].
The Steam Gaming Platform statistics for July 2019 show that the number of active users per day is around 15 million [4].

According to March 2017 data released by Google official Sameer Samat, the most downloaded Android-based five games were Candy Crush Saga, Subway Surfers, Temple Run 2, Despicable Me, Clash of Clans, respectively [5]. According to Google Play data of December 2017, the number of games with more than 500 million downloads shows the size of the sector [6, 7, 8, 9, 10, 11]. In the 2018 report of Newzoo, when the market size is analyzed according to the digital game segment, mobile phone and tablet games rank first with 51%, followed by console games with 25% and PC games with 24%. According to the same report, the fastest growth is seen in mobile games [2]. Among the reasons for the rapid growth of mobile games; the ease of use and the needlessness of additional hardware, and the ability to develop and market games in the mobile environment are easier compared to the PC and console. With the improvement of the technical capacities of phones and tablets, it is possible to develop games using big budgets and online services. Even with a simple interface, a puzzle game developed by a single developer, can achieve large revenues [3].

There are many educational games developed today and many researches on these games. The first educational computer game aimed at students was produced in 1971 by the MECC research center under the name Oregon Trail. In 1973, a project called Plato was developed in which educational computer games were used for mathematics education. The computer game developed within the scope of this project was tested on students. As a result, positive effects on mathematics achievement and student attitudes towards mathematics were observed. In 1982, Rocky Boots, a game developed for high school students to design digital logic circuits, sold 100,000 units [12].

The more sensory organs address a teaching activity, the better the learning becomes more permanent, the more late it is forgetting. The use of instructional technologies and materials in education; it

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is used to provide educational services to the wider masses, to make learning-teaching processes efficient in educational institutions and to individualize learning-teaching activities [13].

Recent research has shown that students spend more time on computer games than watching television and reading books. This activity, which the students spend time, can be turned into a more efficient one in collaboration with educators and game makers [12].

Some of the benefits of digital games can be listed as follows. It provides active, experimental and problem-based learning. Develops independent and critical thinking skills. Improves the ability to do multiple jobs by enabling multiple tasks to be performed simultaneously with strategy games. It can be especially helpful for children to develop basic mathematics, reading and language skills. Improves focus, hand-eye coordination, and the ability to visually track many objects at the same time. The communication environments created by the players support fast and effective communication. It can contribute to the development of digital literacy skills of children who are introduced to computer games at an early age. Movement-based games, called "Exergame", which require physical interaction, can especially allow children to spend their energy and make the necessary movements for their physical development. With the games played in the virtual world, the rules of real games can be learned. It has been observed that it helps individuals with multiple disabilities to develop their spatial, mathematical and problem solving skills. It may support the treatment processes of some diseases. It can enable players to set a target for themselves, to strive to achieve their goals, to experience the sense of success many times and to continue their success [14, 15, 16, 17, 18, 19].

Korkusuz and Karamete reported that Bartholomew et al. used the computer game they developed to teach asthmatic students to fight the disease. As a result of the study, it was stated that the number of hospitalization asthmatic students decreased, fewer symptoms were observed and these students were able to perform their daily activities more comfortably [20, 12].

Education in digital games usually comes in two ways. The first is the use of existing games as a training tool on a specified topic, and the second is the use of specially designed and developed games to assist education on a particular topic. As an example, Parker's research [21] used "Age of Empires II" to understand the subject of "Multimedia Production Management", Mayer and Bekebrede's [22] simulation games "Containers Adrift, Ventum Online, Sim Mv2" to be investigated in use in places such as ports, terminals, wind farms to be used to set policies and used in decision making phases, in Yang's research [23] to develop problem-solving skills in Citizenship and Society course the use of the simulation named "Sim City Societies" can be given. HTC Blood Test Game which was developed together with Compultense University Medical Faculty educators [24], Alan's "Algorithms in Computer Sciences" is a 3D game [25] which aims to explain the subject of "algorithms", the educational game that Navruz et al. suggested [26] to be used in mathematics lessons which is the basis of this research can be given as an example for the second.

It has been mentioned in various studies on the development of educational games: the importance of the balance between playing and educational goals [27], careful design of levels [28], understanding the interaction of players with the game environment [29].

There are different methods that can be used to develop educational games. One of them, the Experiential Game Model, was proposed and developed by Kiili [12].

The educational game developed in this study; was developed to provide a more fun learning environment using electronic devices to support standard classroom teaching activities and to enrich the activities in order to help a direct understanding of the subject, thus enabling more effective learning.

2. Material and Method

2.1. The Purpose of the Game

Primary School Mathematics Course Curriculum consists of four learning areas which are; Numbers and Operations, Geometry, Measurement and Data Processing. All learning areas take place at each grade level, while some sub-learning areas come into play after a certain class. Of these, the Geometry gains are at all grade levels of the program. Secondary School Mathematics Course Curriculum consists of five learning areas which are; Numbers and Operations, Algebra, Geometry and Measurement, Data Processing and Probability. Achievements in the field of ''Geometry and Measurement ''are included in all classes. At the 8th grade level, translation and reflection transformations are given within the lower learning area of transformation geometry. The concepts of parity and similarity are examined in polygons and students are expected to identify and form identical and similar polygons [30].

The symmetry that gives the game its name has an important place in the field of Geometry. In the "Mathematics Course Curriculum" of 2017 achievements of the students are given as such; in the 2nd grade the student "Recognizes the symmetrical shapes around it.", in the 3rd grade the student "Determines the shape of more than one symmetry line by multiplying the shape." and "Completes the given symmetric shape according to vertical or horizontal symmetry line.", in the 4th grade the student "Draws the symmetry line by explaining the mirror symmetry on geometric shapes and models.", and "Draws the symmetry of the given shape according to the line.", in the 5th grade the student "Expresses the position of a point relative to another point using direction and unit.", in the 8th grade the student, "Forms the image of the dot, line segment and other shapes as a result reflection", "Creates the image of the polygons as a result of translation and reflections." Of them, the 8th grade "The student forms the image which is a result of the reflection of the dot, line segment and other shapes." includes the 4 following matters [30]:

a) Work on squared or dotted paper, coordinate system. b) Studies to be done with dynamic geometry software can also be included. c) In the reflection, it is made to be noticed that the points corresponding to each other on the figure and the image are perpendicular to the symmetry line and that the distances between them are equal and therefore the figure and the image are identical. d) Studies are also made with the shapes on the symmetry lines.

The main aim of the game named Simetri developed in this study is to create an entertaining environment for the students to gain the above mentioned matters and to support the conversion of these matters into gains with the help of the game.

2.2. Game Introduction

The game consists of a home screen and Game Screen. On the home screen, there is the name of the game, the area where the stages can be selected, the button to start the game, and at the bottom there are buttons for the score table, how to play, and about the game. There are two parts in the game area, tools and time, score information is located at the top, just below the game area. The play area consists of the area where the automatic drawings are created, the axis of symmetry and the drawing area.

There are three difficulty stages in the game. Game stages are

determined by the number of squares and dots, one dot in every 50 pixels in the "Simple" stage, one dot in every 25 pixels in the "Normal" stage, one dot in every 10 pixels in the "Advanced'' stage, and the stage system designed with squares which form as a result of the combination of the dots in every stage.

Each stage of the game consists of eight chapters and it is not possible to move to the other chapter before each chapter is finished. 180 seconds are given to complete the chapters. If it is finished within this period, additional points are taken in proportion to the remaining time. For the sections that cannot be completed within this period, the game does not end and the drawing process can be continued -because of the educational game-, but no points are given for the operations performed after the period ends.

Scoring starts by giving 10 points for each correctly marked point, this is calculated by multiplying by certain coefficients according to the stages. 100 points are awarded for each figure completed within the time period and this score is calculated by multiplying by certain coefficients according to the stages.

In each level of the game, the polygons are created, the edge numbers of these polygons begin with 3, and the level is completed after the symmetry of a polygon with 10 edges is drawn which increases by 1 each time.

2.3. Development Phase

2.3.1. Determining the Structure of the Game

Two points were taken into consideration when determining the structure of the game. The first is the low hardware requirement and the second is the prevalence of the operating system. Keeping the hardware requirements low for the game to appeal to more people, the operating system also supports mobile operating systems and because a large number of students or parents have a smartphone or tablet computer the game can be easily accessed.

2.3.2. Selecting the Development Environment

Priority is to select a program capable of exporting to various environments so that the target system includes mobile operating systems and does not interfere with the use of machines with other operating systems. Especially the necessity of writing a game with HTML5 support has emerged at this stage. This preference has come to the fore as the current versions of the most common Internet browsers have HTML5 support, which will ensure that the game plays smoothly on every machine with this software.

At this stage, the software called Construct 2, has been preferred because it will develop an HTML5-based game, as well as providing it to export to mobile operating systems, having a plug-in that can be exported to the desktop version [31]. This enabled the game to run on many desktop computers and mobile devices with Android and IOS operating systems. The free version of "Construct 2" allows you to write up to a certain line of code and work with a certain number of layers, but the free version only allows you to export them as HTML5. Following the purchase of a license, both these restrictions are removed and the number of export environments increases. Other options among these environments are shown in Figure 1.
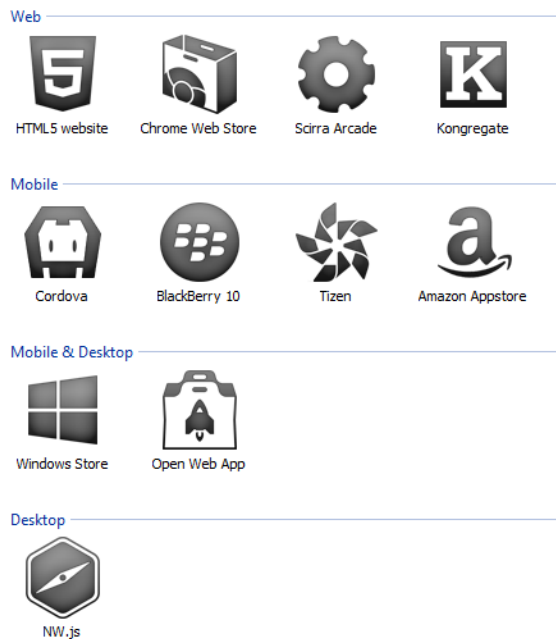

Fig. 1. Environments where Construct 2 software can export games.

2.3.3. Software and Hardware for Game Development

In the development of the game, "Construct 2" software r249 64bit was used as the basis and "Inkscape" software 0.92.2, which is open source for drawing all the graphics in the game, was used. Tests of the game have been performed with various versions of "Mozilla Firefox", "Google Chrome", "Microsoft Edge" and "Opera" internet browsers. The sounds used in the game were taken from "freesound.org". The development process was performed on two computers with Windows operating system.

2.3.4. Game Development

In this section, the work done during the development of the game and their brief descriptions will be given.

2.3.4.1. Interface Design of the Game

Before starting the development process, a two dimensional game domain draft had been created considering the suggestions of several mathematics teachers. While defining this outline, both an environment in which students can easily transfer what they know to the software and a successful interface design has been tried to be revealed. During this design, Visual Arts teachers' opinions were taken and notification screens were formed.

In the course of creating a game domain, with reference to the "Studies are conducted on the squared or dotted paper and coordinate system." which is included in the mathematics course achievements, these three types of backgrounds were included in the game and a button was designed and turned on and off depending on the choice of students. Figure 2 shows a screenshot of these areas.
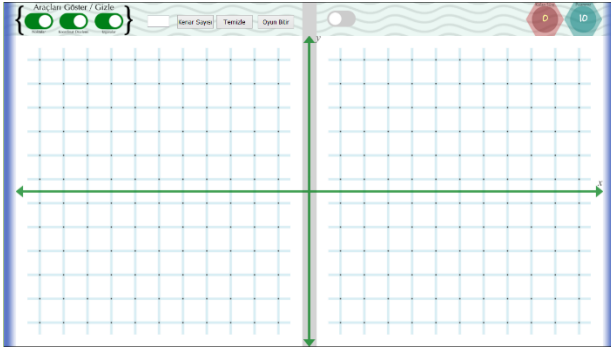
Fig. 2. Playing field - coordinate plane with dotted and checkered paper.

The introduction of the game is also designed so that the playing field is not initially opened. In this section, the name of the game "Simetri" is written and a shaded symmetry is drawn below. The stage selection area of the game, which consists of three stages just below it, is designed. The touch area named "Start Game", which is located just below any one of these stages, is designed in the same color as the selected stage and is designed to have a growing and shrinking animation. In the lower part, two touch areas named "Points Table" and "How to Play?" and the "H" icon in the lower right part created a touch area that will open the part where the information about the game is located. The described elements are shown in Figure 3.

Fig. 3. Game login screen.

Notification screens of the game; the "your name" screen, the "congratulations, section completed" screen after successful drawing of the symmetry of the figure, the
"congratulations, level completed" screen after the completion of the sections found in the level, the "time up" screen that comes up when the given shape isn't completed in time and "congratulations, new record" screens when the score exceeds the highest score in the game. Two of these are shown in Figures 4 and 5.
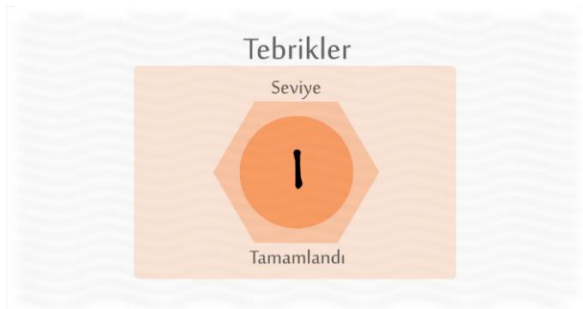
Fig. 4. "Congratulations, level complete" screen.
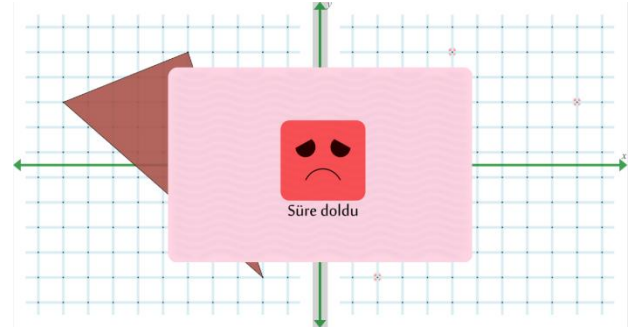
Fig. 5. "Timeout" screen.

The tiny notifications in the game; the "positive notification" icon and sound when the correct edge point is checked, the "negative notification" icon and sound when the incorrect edge point is checked, to prevent the selection of the wrong edge point again, the "wrong point" icon which disappears after 20 seconds, the "correct point" icon which is visible after the correct choice of point, "Point" icon, when the measurement tool is opened and the choice of points that are wanted to be measured, "Measurement Line" icon, that shows a measurement has been done. Figure 6 shows some of these icons.

Fig. 6. Positive and negative notifications.

In the area just above the playground, there is a "Show / Hide Tools" section where you can change the characteristics of the paper type being worked and three feature on-off buttons, as well as a "Ruler" button for turning the measurement tool on and off. On the right side of the same field are the "Remaining Time" and "Scores" sections.

2.3.4.2. Game Coding
The coding area of Construct 2 has a different design that allows coding with the help of a more visual interface instead of a text-only editor. It would not be wrong to say that, this interface is difficult to get used to for people who develop software with a normal programming language.

While developing the game, first the field boundaries had been determined and then the scenario of the stages and the sections within them had been determined. After that, the insertion of the points and squares into the field is performed by using code completely. Especially since the presence of too many objects in the "Advanced" stage has a serious impact on performance, this method was later changed to make the game much more performance with an object called "Tiled Background". Figure 7 shows an overview of the development environment and the coding area.
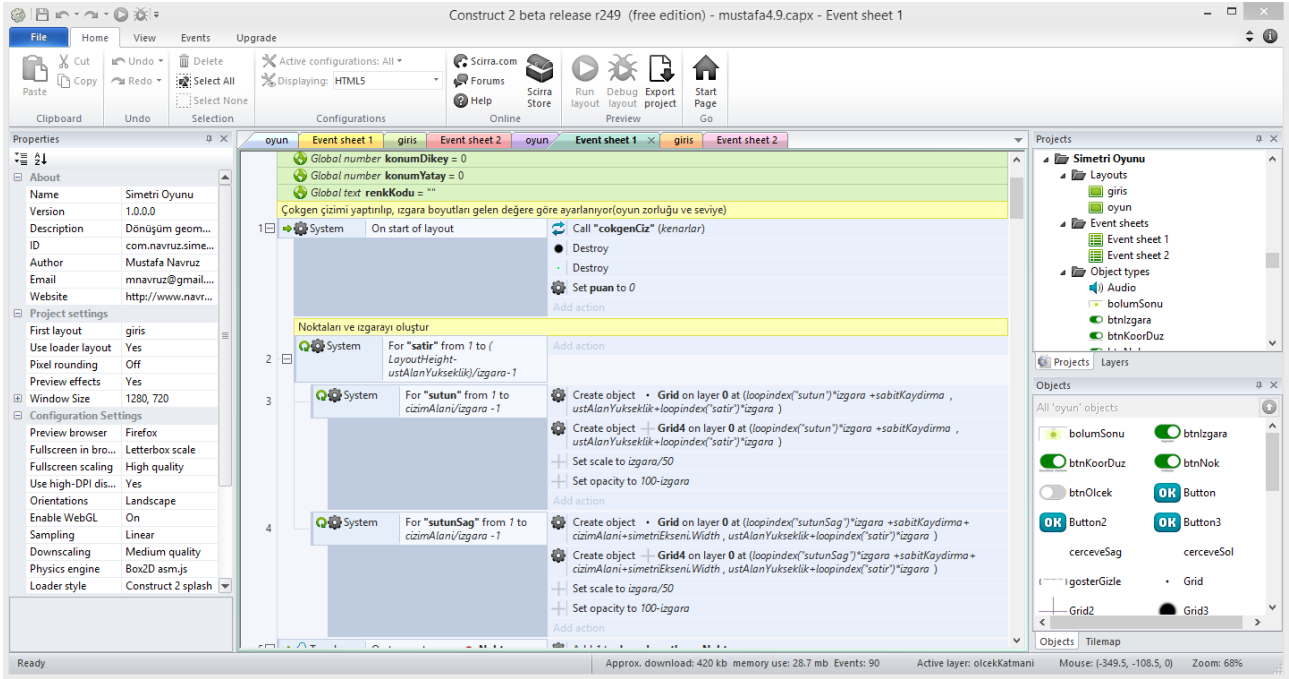
Fig. 7. Construct 2 overview and coding area.

The stages are basically adjusted to the grid sizes and this value, which is held in a variable, is used for calculations in various parts of the game. The grid size is determined by the stage initially selected.

The formulas in Figure 8 were used for the determination of the corners of the polygons plotted in each section, thus trying to prevent the edges from crossing each other.
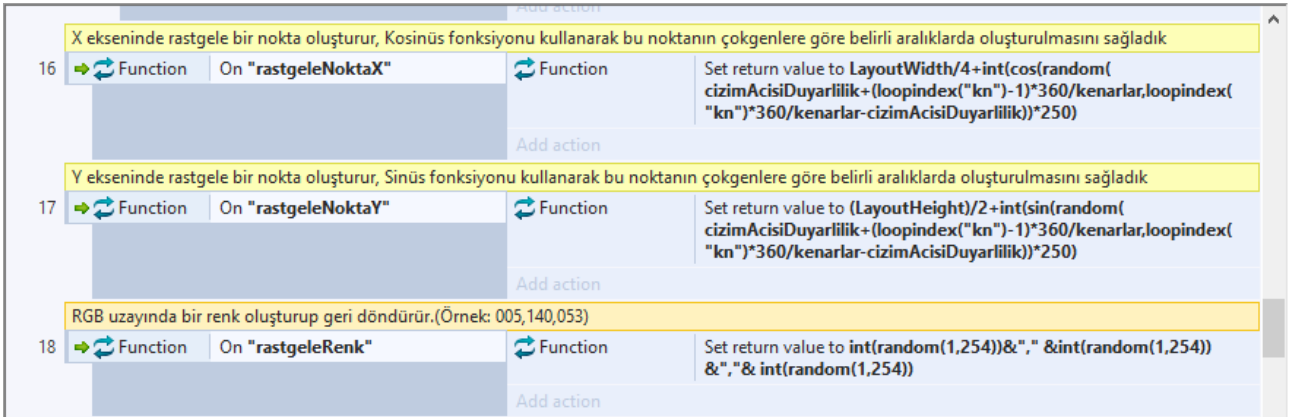

Fig. 8. Sub-functions used to determine the edges of a polygon and assign its color.

According to these points determined by the formulas of Figure 8, it is provided to attach the corner values of the polygon over the points formed according to the stage. Following the random

assignment of the color of the polygon, the polygon plotting is performed. Part of the function that performs these operations is given in Figure 9.

Fig. 9. Function used to draw polygons.

After drawing the polygon, the symmetries of the corner points are also calculated. If the player finds and touches any of these, the point is colored after the feedback is made, and when he finds all the corners, the symmetry of the polygon is plotted and gradually revealed in an animated way. Some of the codes used to perform these operations are given in Figure 10.

Fig. 10. Part of the code used to plot the symmetry of the polygon with the player's touches.

Considering that it is not always possible for players to mark points exactly on the screen; each touch is taken by attaching to the edges according to the point dimensions and the touch space is reduced according to these values. The codes used to do this are given in Figure 11.
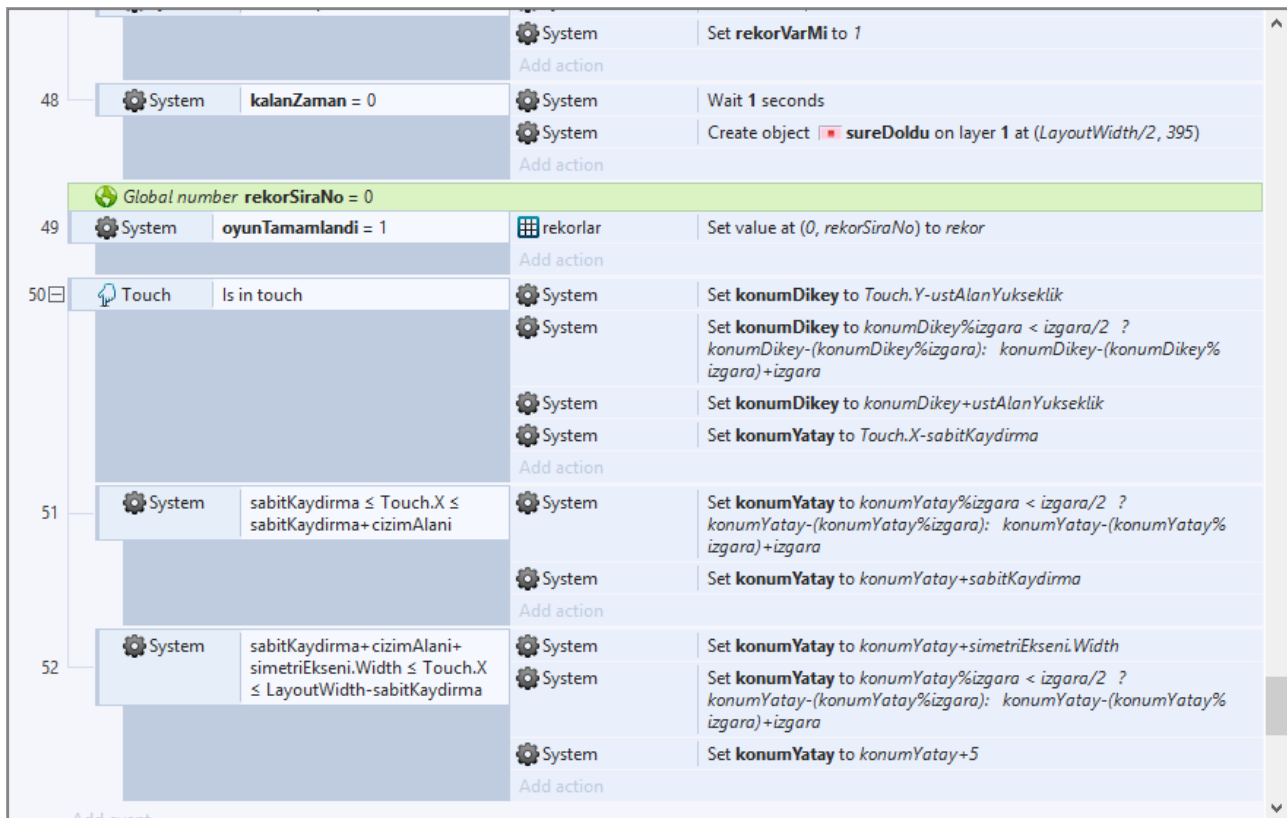

Fig. 11. Codes used for touch improvement.

3. Conclusions and Recommendations

The impact of computer games on students' academic achievement has been the subject of numerous researches. Some of these studies focused on determining the effects of games on academic achievement without examining computer games, while others tried to determine this effect on the basis of a few games. Research shows that computer games can have different effects in different sexes, and different effects can be seen at different ages. There are studies showing that the time spent on computer games may also lead to different outcomes [32, 33, 34, 35, 36]. All of these show a sophisticated relationship between academic achievement and computer games. To determine this relationship, the results of different studies should be examined carefully.

The role of computer games on academic mathematics achievement according to students' previous knowledge of mathematics, computer skills and foreign language skills was also examined [37]. However, with regard to the impact of computer games on the speed and attention in mathematics learning, it is recommended that teachers use computer games together with traditional methods in classrooms [38].

In literature, the use of ready-made games together with the lessons is exemplified. Less number of applications developed on the basis of courses or subjects. In the publications of these applications, it is seen that the preparation stage of the game is not mentioned much. There are not many indications that the rules are adhered to in terms of reflecting the skills to be acquired in the software. Our study is distinguished from the similar ones in terms of development of the application depending on the course and subject gains.

The developed game aims to provide an environment where students can reinforce what they learn while having fun. The game has been tried to be developed in such a way that it can be seen whether the students have achieved the gains stated in the curriculum. Thus, it can be used both as a support during the lecture and as an indicator during the assessment. The game is expected to benefit students and teachers throughout the process. The game which is developed with Construct 2 software development tool, is based on drag and drop method to create. This may be convenient for those who are not familiar with writing code directly. For those who know coding can be seen as a negativity.

It is a great advantage that the game can be developed for mobile environments and can be used on desktop computers at the same time. The software development tool having the ability to be exported to different environments provides a serious convenience.

The benefit of the game in a classroom setting, during or after the lecture, can be measured. The software can be improved by taking the opinions of teachers and students.

It is predicted that the thorough explanation of the development methods of the game will be beneficial for the future studies.

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