Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)
Vol. 8, No. 1, March 2022, pp. 27-37
ISSN: 2338-3070, DOI: 10.26555/jiteki.v8i1.22200

Simulation of Logic Circuit Tests on Android-Based Mobile Devices

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ARTICLE INFO

Article history:

Received November 09, 2021
Revised March 29, 2022
Accepted April 05, 2022

Keywords:

Logic Circuit;
Mobile Application;
Simulation;
Unity

ABSTRACT

In this study, an application that can run on Android and Windows-based mobile devices was developed to allow students attending such classes as Numerical/Digital Electronics, Logic Circuits, Basic Electronics Measurement, and Electronic Systems in Turkey's Vocation and Technical Education Schools to easily carry out the simulation of logic gates, as well as logic circuit tests performed using logic gates. A 2D-mobile application that runs on both platforms was developed using the C# language on the Unity3D editor. To assess the usability of the mobile application, a one-hour training session was administered in March of the 2017-2018 academic year to two groups of students from a single class in the sixth grade of an Imam Hatip Secondary School affiliated with the Ministry of National Education. Each of the two groups contained 12 students who were assumed to be equivalent and who had no prior knowledge of the subject. The training of the first group began with a lecture on basic logic gates using a blackboard and involved no simulations. In comparison, the second group was given the same lecture and received additional training involving demonstrations of the developed mobile application and its simulations. Following the lectures, a written exam was applied to both groups. An evaluation of the exam results revealed that 83 percent of the students who had been given demonstrations of the mobile application were able to perform the circuit task completely, whereas only 50 percent of the others were able to complete the task. It was concluded that the application was both useful and facilitating for the students, and it was also noted that students who were supported by the mobile application had gained a better grasp of the topic by being able to see and practice the simulations firsthand.

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1. INTRODUCTION

Education occupies an important place not only in the school life of individuals but also in every aspect of daily life. Recent technological developments have led to the emergence of countless new learning environments for individuals, with one such environment being the medium provided by mobile devices and tablet computers, which can be accessed independently of location and time. These technologies are becoming more indispensable with each passing day, and the interest of students in different courses, as well as their levels of achievement, can be increased by rendering abstract concepts more tangible through the use in classes of the mobile simulation applications that have become widespread in recent years. Mobile learning software can also reduce the challenges experienced in real applications and can circumvent the potential risks to which users may be exposed while also allowing learning whenever needed, with no constraints of location or time.

Akçay [2], a web-based virtual laboratory application, has been developed for the courses which are called logic circuits, digital electronics, or logic circuits in the lesson plans of both high schools and universities. The virtual laboratory application was created using ASP.NET WebForms and C# programming language [2]. In another study, Çınar [7], a microcontroller-based integrated test circuit has been designed for use in logic circuit laboratories [7].

The study of Karunaratne [18], in this work, discusses various aspects of student learning based on a project to develop a primitive digital electronic circuit simulator at the undergraduate level within the Computer Engineering program at the University of Pittsburgh at Johnstown, PA [18]. Kavak [19], a learning environment was designed with the design-based research method in line with the needs of the students, and it was aimed to fill the practical deficiency of the students in the Electronic Circuit Elements course [19].

Khairudin et al. [20] provide the development of a virtual laboratory for the subject of digital engineering. This study applies a virtual laboratory to mobile virtual reality for a virtual digital engineering laboratory [20]. In their study, Mohammed et al. [22], efforts have been made to provide methods for developing a prototype training kit (called e-Logic training kit or e-LTK) consisting of an electronic simulator and exam assessment module to assess subject knowledge on logic gates [22].

Rajasekaran and Sundari's [23] work has given the simulated and comparative analysis study of logic gates with the mix of typical CMOS devices, SET, and also in hybrid circuits. The logic gates are NOT, NOR, and NAND designed and simulated using SPICE machine and analyzed the performance [23]. Seraj et al. [24], a web-based survey study was conducted to determine the perceptions of students and instructors about the self-implementation of logic circuits via mobile devices [24].

Seraj [25], in the study, a mobile-based learning prototype is presented on the subject of "logic circuit design" learning [25]. In their study, Tafrikhatin et al. [26], in this work, aimed to know the impact of mobile learning media on the subject of basic logic gates in the learning process of second-grade students of vocational high school [26].

Abrishami et al. [1], in their work, they present CSM-NN, a scalable simulation framework with optimized neural network structures and processing algorithms [1]. Alioon and Delialioğlu [3] designed, developed, and implemented original, collaborative mobile learning activities for a computer networking course. The aim of the research is to determine the effect of activities on student participation and motivation [3].

Astuti et al. [4] conducted research to determine the effect of a mobile application on the development of students' critical thinking skills in physics teaching [4]. Bayram [5], the effect of 7th-grade students' understanding of electricity concepts and their interest in electricity was investigated by using simulations and the 5E learning cycle model [5].

Bektaş [6] investigated the secondary school students' use of mobile applications for educational purposes and the relationship between them with various variables [6]. In Demiray [8], here Android application has been developed in order to ensure that the victims of diving accidents reach the treatment centers as soon as possible, start the treatment as soon as possible, and raise awareness about diving accidents and their areas of influence and benefits are expressed [8].

Doğan [9], how multicellular living embryos mature in the mother's womb or in the egg was investigated, a simple simulation of this mechanism was made, and the success of the method in producing original 3D designs was examined. The application is developed with the Unity3D game engine [9]. In his study, Dube [10], virtual reality-based interface, augmented reality-based interface, and touch-based mobile application are defined on the Android platform. Unity3D program was used to develop the interfaces. In this study, the effects of different interaction techniques on user experience for a choreography generator were investigated [10].

Etcuban and Pantinople [11] conducted research to determine the effects of mobile application use in mathematics teaching at the high school level [11]. In a study, Gençer [12] examined the graphic design problems of mobile educational applications designed for preschool children and presented an exemplary educational mobile application design as an application project [12].

Gezer [14], the effect of activities based on mobile applications on academic achievement, critical thinking skills, and motivation in the social studies course was investigated [14]. Heflin et al. [15], the effectiveness of mobile education applications in the cooperative learning system was tested in three different cooperative learning environments, both with and without mobile technology [15].

Jeno et al. [16] conducted research to determine the effects of a mobile application they developed for the identification of species on the academic achievement, competence, and autonomy feelings of biology students [16]. Karasaç [17] reveals the effect of mobile application-supported environmental education on the academic achievement of fifth-grade students, their attitudes towards technology, and the environment [17].

Koparan and Yılmaz [21], the mobile learning environment, and the opinions of teacher candidates about the learning environment supported by mobile learning were examined [21]. Tanır [27], in order to determine the possible effects of mobile learning on the German vocabulary learning achievement of the undergraduate students of the Department of German Language Teaching, the Mobilmetri application compatible with smartphones was used [27].

In his study, Toy [28], mobile education applications designed for fifth-grade students aged 9-11 were examined, and an analysis of identified user interface design problems and design suggestions determined as a result of these analyzes were presented [28]. Yaşar [29], an android application, has been developed for mothers and expectant mothers. An application has been designed in which both mothers can access the vaccination information required for their children aged 0-2 and that the expectant mothers can follow their pregnancy information week by week [29].

Yıldırım [30], The feasibility of mobile learning in Vocational Schools was investigated, and for this purpose, a mobile learning environment was designed by the researcher for the "Introduction to Algorithm and Programming" course, which was observed to be difficult for learners to achieve [30]. Yokuş [31], a mobile application aimed at improving the knowledge and skills of the undergraduate students of the Faculty of Education for the Teaching Principles and Methods course, was designed and used practically in a classroom for two months [31]. To investigate the impact of mobile technologies on student performance, Kalınkara [13] used the Android operating system platform to develop an application covering the subjects in the Computer Hardware and Electronics course [13].

With each passing day, Android-based smart devices are gaining more significance in our daily lives, and foremost among these devices are smartphones and tablet PCs [32]. Over time, there has been a growth in the number of projects carried out that take advantage of the superior features of these devices, which greatly facilitate human life. With the prevalence of these portable systems, people are today able to access many applications without being hindered by the constraints of time or space.

The rapid development of technologies has also had a profound effect on education. The use of smart boards in educational institutions, the provision of tablet computers to students, and the ability to follow lessons via the Internet are just some examples of the close relationship between technological development and educational tools [33].

In recent years, there have been a variety of mobile applications and academic studies developed in many fields based on simulation-based learning. A review of literature uncovers several Android-based mobile applications related to the use of Logic Gates and Logic Circuits that are available from Google Play. That said, it is apparent that while academic studies conducted on this subject have addressed the development of computer-aided simulation applications, there have to date been no mobile simulation applications developed that are capable of running on both Android and Windows platforms.

In the present study, an application is developed that can run on Android- and Windows-based mobile devices. A 2D application was developed in C# on the Unity3D editor that allows students to carry out simulations of logic circuit tests, prepared using logic gates either during class or at a time and place of their choice, and which are also capable of operating on the Tablet PCs distributed in schools within the scope of the FATİH Project (Project to Increase Opportunities and Improve Technology), on personal mobile phones, and on Windows-based interactive boards and touchscreen laptops.

2. METHOD

In the study, a mobile application has been developed to simulate logic circuit experiments on Android and Windows-based mobile devices. The images of the logic gates and other logic input-output units used in the implemented mobile program were arranged in Adobe Photoshop and Fireworks programs. The mobile application is prepared in Unity3D Game Engine, using C# programming language. The code structure in this language is in the form of object-oriented programming.

Visuals of logic gates and other logic input-output units are defined as Prefab in Unity. Multiple GameObjects can be created from Prefab. This operation is called instancing. Because they are defined as prefab, logic elements can be added and used in large numbers in the scene. While creating the prefabs, the input-output pins of the elements are added as a child since the connections will be established over the pins.

It is ensured that every element on the stage is moved to its place by the drag and drop method. The connections between the pins of the circuit elements are made by defining class, and the Unity Line Renderer component is used to draw or delete the lines. This script component, which is added to each pin object, helps you to connect or break the connection between pin objects in different logic gates.

In addition, the load (logic 0 or 1) transfer between the pins is carried out by defining the class and added to all pin objects as a component. In this way, it is ensured that the loads are transferred when the connection between the circuit elements is established. On the logic gates, scripts that enable them to do their own tasks are also added to the gates as a component.

2.1. Software of the Used Simulation

The mobile application comprises two parts: The Home Screen and the Simulation Screen. The Home Screen contains New, Help, and Exit buttons, as can be seen in Fig. 1.

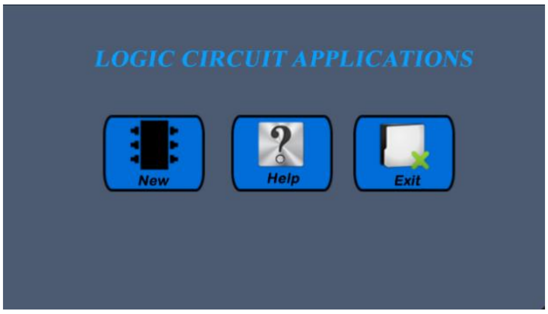

Fig. 1. Home screen view.

The Exit button on the screen is used to completely exit the software, while tapping the New button opens the Simulation screen, where a new circuit application can make. Fig. 2 shows the Simulation screen on which the circuit applications are carried out. A small code ensures the screen remains horizontal during the operation of the software, facilitating use.

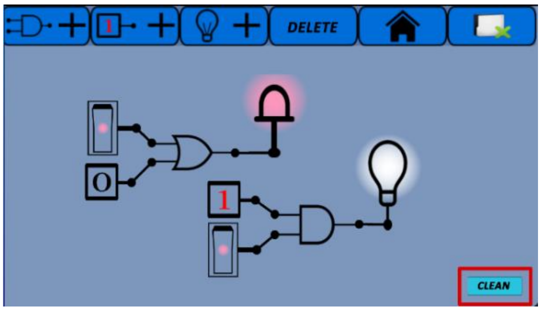

Fig. 2. Simulation screen view.

Tapping the Help button opens the Help screen shown in Fig. 3, where an explanation is given of how the software operates. The button at the bottom of the screen is used to return to the Home screen.

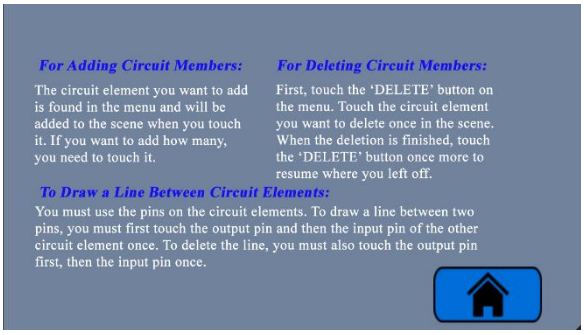

Fig. 3. Help screen view.

2.1.1. Simulation screen

The Simulation screen is where the applications will be performed and contain the menu from which the necessary circuit elements can be selected. The desired circuit elements are selected from the drop-down list and then added to the circuit. From the menu, it is possible to perform the Add Logic Gate, Add Logic Entry, Add Exit (lamp or led), Delete, Go to Home Screen, and Exit functions. Fig. 4 shows the layout of the menu.

Fig. 4. Simulation screen menu view.

a. Add Logic Gate Button. Tapping the Add Logic Gate button, which is the first option on the menu, opens a list of the gates that can be selected and added to the screen. When any one of the listed gates is tapped, the selected gate appears in the center of the screen. Fig. 5 shows the drop-down list of the Add Logic Gate button.

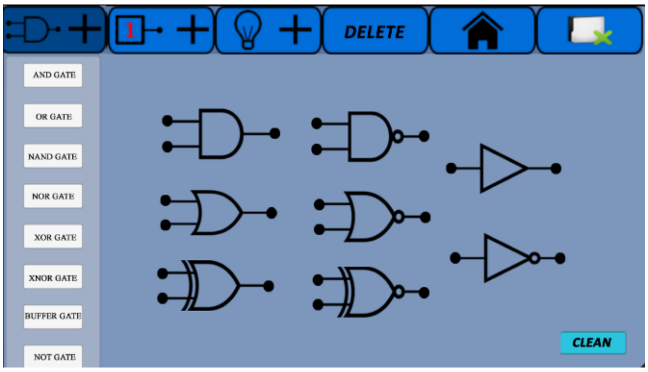

Fig. 5. Add Logic Gate button.

b. Add Logic Input (Load) Button. Tapping the Add Logic Input button, which is the second option on the menu, opens a list showing the inputs that can be selected and added to the screen. The three available options are Logic 1, Logic 0, and Switch. Fig. 6 shows the list that opens when the button is tapped.

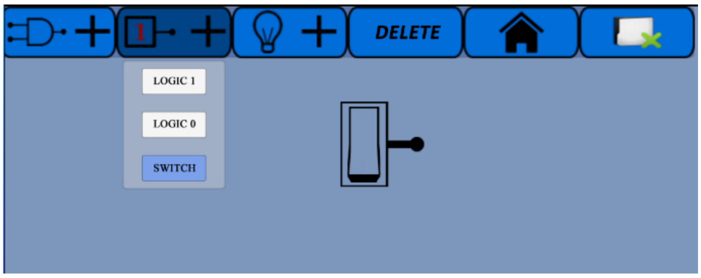

Fig. 6. Add Logic Input button.

c. Add Exit (lamp or led) Button. Tapping the Add Exit button, which is the third option on the menu, opens a list of the available exits (lamp or led) that can be added to the screen. Operation of the circuit is ensured by having the lamp or led remain on or off, depending on Logic 1 or Logic 0, arriving at the outputs of the circuit relative to the inputs. Fig. 7 shows the drop-down menu that opens after tapping the Add Exit button.

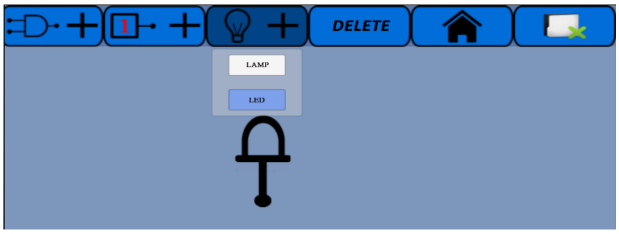

Fig. 7. Add Exit button.

d. Delete Button. The Delete button on the menu is used to delete circuit elements. Tapping the Delete button causes the name of the button to change to "DELETE ACTIVE," and the circuit element on the screen can be deleted by tapping the circuit element selected for deletion. All other elements intended for deletion can be removed using the same method. To continue setting up the circuit once the delete process has been completed, tap the Active Delete button on the menu to change its status back to "DELETE," after which the editing process can be continued. Fig. 8 shows both the passive and active statuses of the Delete button.

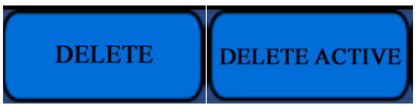

Fig. 8. The Delete button.

e. Go to Main Menu Button. When the Go to Main Menu button shown in Fig. 9 is tapped on the relevant menu, a pop-up window opens on the screen asking for confirmation whether the user wants to return to the Main Menu (Home Screen). As shown in Fig. 10, touching the Yes button on the screen returns the user to the Home Screen, while touching the No button returns the user to the screen on which the circuit is being constructed.

Fig. 9. Go to the Main Menu button.

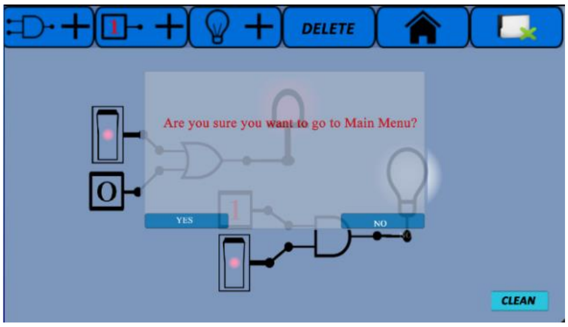

Fig. 10. The pop-up window that appears when the Go to Main.

f. Exit Button. Tapping the Exit button shown in Fig. 11 opens up a pop-up window on the screen asking for confirmation that the user wants to exit the program. As shown in Fig. 12, the window in question closes if the Yes button is tapped, while touching tapping the No button returns the user to the screen on which the circuit is being constructed.

Fig. 11. Exit button.

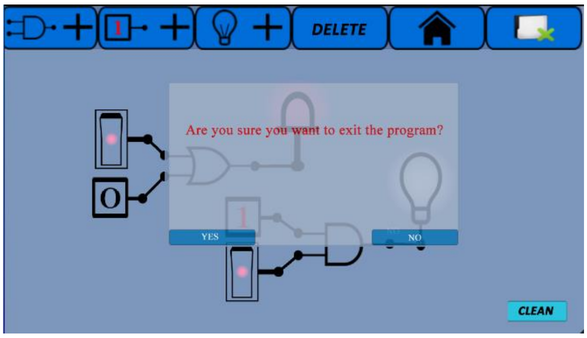

Fig. 12. View of the window opened by tapping the Exit button.

g. Clean Button. Fig. 13 shows the Clean button, which is located in the lower right-hand corner of the screen and is used to clear the screen completely, allowing a new circuit to be set up. This should not be confused with the Delete button, was is used to delete specific elements on the screen.

Fig. 13. Clean button.

2.2. Flow Diagram of the Simulation Software

The circuit elements needed to establish the circuit are selected from the menus and added to the screen. Each element on the screen is moved into position with a “drag and drop” action. If a circuit element is added by mistake or in excess, it can be deleted from the screen using the Delete button. Finally, connections are made between the pins of the circuit elements, with each connection having to be made one by one. To make a connection, first tap the output pin, followed by the input pin or led pin of the gate to which it is to be connected, taking the direction of the loads into account. The loads are transferred by making connections between the circuit elements. The scripts on the gates that allow them to execute their tasks are added as Components. In these scripts, loads arriving at the inputs of the gates are processed in line with the function of the gate, and the results are transferred to the output pin. Once the connection has been established, the load of the result value is transferred to the next gate or led in line. Fig. 14 presents a flow chart of the running program.

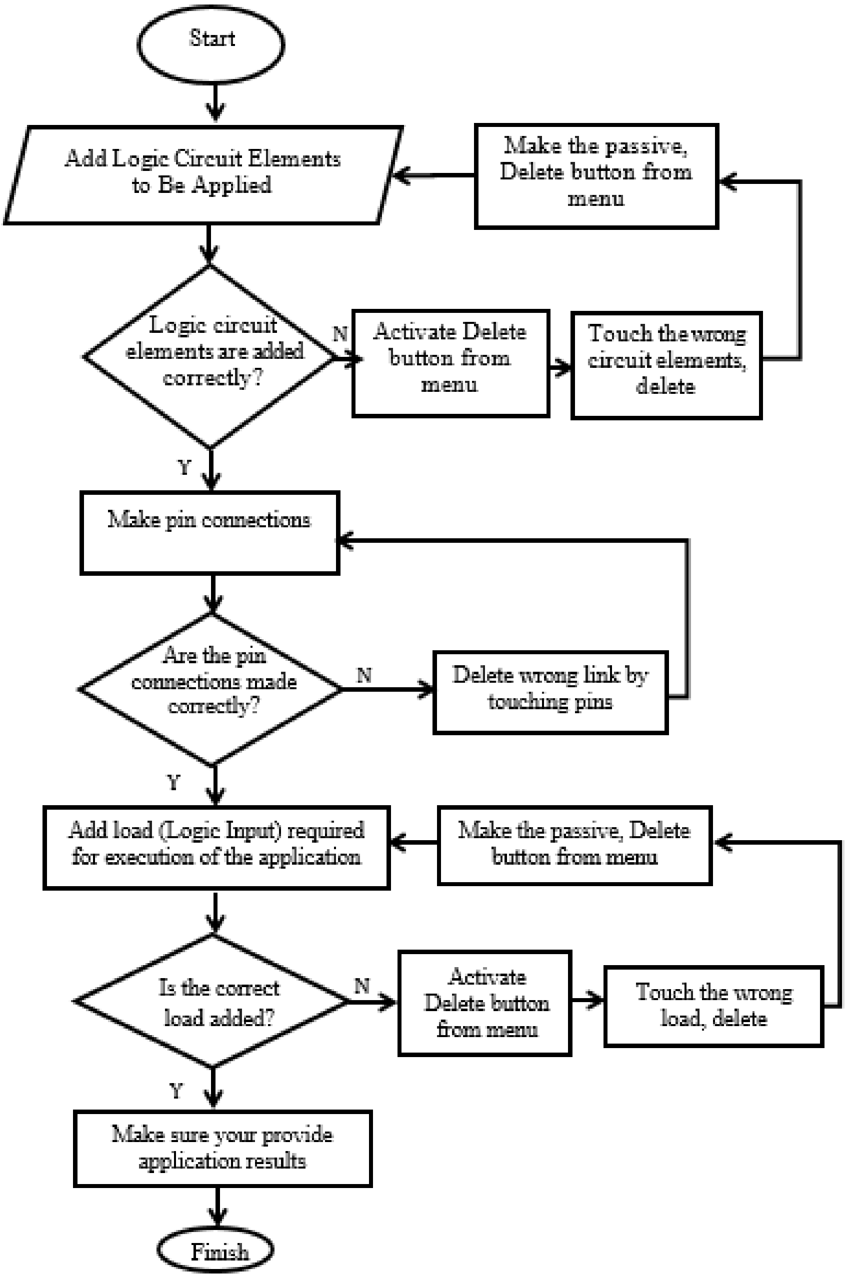

Fig. 14. Flow diagram showing the operation of the program.

2.3. Zooming and Panning on the Screen

While setting up a circuit using the mobile application, it is possible to zoom in or out on of the screen and pan up, down, right, or left. After zooming in or out and/or completing the circuit, all returning the application to its normal appearance can be achieved by double-tapping an empty area on the screen.

2.4. Example of a Simulation Run with the Developed Mobile Application

Once the software was prepared, various application examples were carried out. These applications were the AND gate practice, the OR gate practice on an interactive board, and a half-adder logic circuit.

2.4.1. AND Gate Application

Fig. 15 shows screenshots of a simulation in which the inputs to the And gate are applied in sequence, with the outputs determined according to the inputs. A Switch was used to apply the input loads.

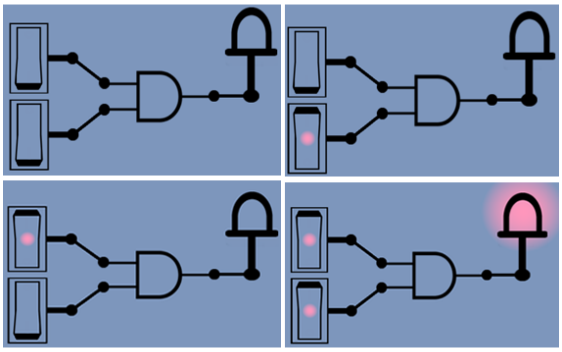

Fig. 15. And gate application screenshots.

2.4.2. Application of an OR Gate on the Interactive Board

Fig. 16 shows screenshots of a simulation in which the inputs to an Or gate were applied in sequence, with the outputs determined according to the inputs. The simulation of the Or gate was performed by running the mobile application on an interactive board.

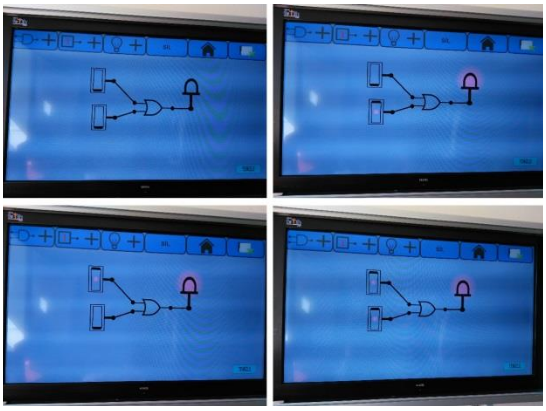

Fig. 16. Or gate interactive board screenshots.

2.4.3. Application of the Half-Adder Logic Circuit

The adder circuit generates results as two outputs in the form of a sum and a carry by adding two bytes applied to its input, referred to as a half-adder. Fig. 17 shows the half-adder symbol, while Table 1 shows the half-adder circuit truth table.

Fig. 17. Half-adder symbol.

Table 1. Half-adder circuit truth table.

A	B	S	C_o
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Fig. 18 shows a screenshot of the simulation in which the inputs given in the truth table were applied in sequence. A Switch was used to apply the input loads. When the key was tapped, its location changed automatically. The Switch passed the Logic 1 load when the light was on and the Logic 0 load when the light was off.

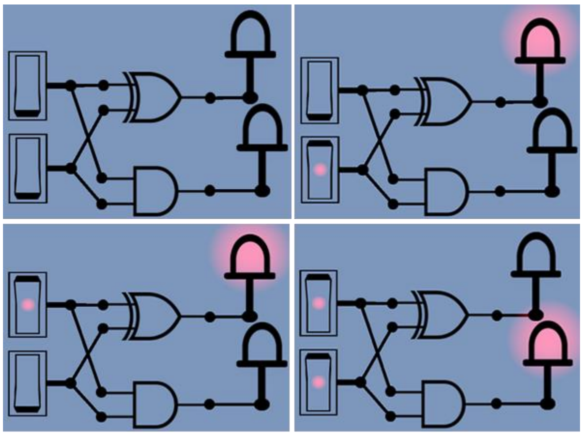

Fig. 18. Half-adder circuit screenshots.

2.5. Use of the Developed Mobile Application in Education

Through this educational instrument, an attempt was made to provide a better understanding of the running of logic gates and logic circuits through the use of simulations. The study was carried out in March of the 2017–2018 academic year, involving two groups of students from a single class attending the sixth grade of an Imam Hatip Secondary School affiliated with the Ministry of National Education. Each group contained 12 students who were assumed to be equivalent and who had no prior knowledge of the subject. The first group attended a lecture about basic logic gates using only a blackboard, with no simulations demonstrated, while the second group, in addition to the lectures, was also shown a demonstration of the developed mobile application and its simulations. During the lesson, the software was run on a touch-screen laptop computer, and the lecture was delivered with presentations using a projector. At the same time, a tablet PC was circulated among the students on which they could perform the simulation themselves. Following the lecture, a written exam was applied to both groups. In the first and second questions of the exam, the input values of logic gates were given, and the resulting outputs were asked. In this section, both groups recorded the same level of success. In the third question, the students were requested and asked to draw a logic circuit using logic gates. In the first group, 50 percent of the students were able to fully set up the circuit, 33 percent could only partially complete the task, and 16 percent were not able to set it up at all. In the second group, 83 percent of the students set up the circuit in full, and 16 percent were only partially able to complete the task. The questions given to the students are presented in Fig. 19.

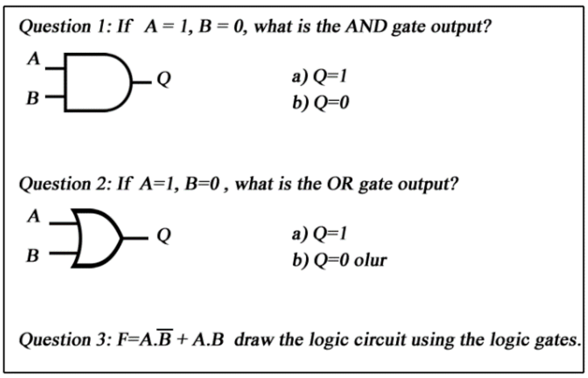

Fig. 19. Evaluation questions.

An evaluation of these results reveals that the students whose education was supported by the mobile application were more successful than the other group, indicating that the application is both useful and facilitating. It was also noted that the lecture delivered to the second group was more effective and that the students gained a better understanding of the topic by being able to see and practice simulations.

3. CONCLUSION AND SUGGESTION

In this study, an application that can run on both Android- and Windows-based mobile devices was developed that allows students attending classes such as Numerical/Digital Electronics, Logic Circuits, Basic Electronics Measurement, and Electronic Systems in Turkeys Vocation and Technical Education Schools to easily carry out simulations of logic gates, as well as logic circuit tests performed using logic gates. The 2D- a mobile application that runs on both Android and Windows platforms, was developed using the C# language on the Unity3D editor. Using this simulation application is offers certain advantages in that it is more secure; it allows, from an educational standpoint, the complexity of the learning process to be controlled; it can be used on both Android and Windows platforms, and it provides cost savings by eliminating the unnecessary use of electronic components.

The developed application can be presented to students undertaking Vocational and Technical Education and can be improved further based on their feedback. Furthermore, the application can be made even more useful through the addition of other logic elements, such as flip-flops, multiplexers, and de-multiplexers and save processes. This work can also be done into a game, and difficulty levels can be created from the circuit provided on the application screen. If the circuit is completed correctly by the user, both the level will increase, and the points will be added. So the system will become educational and entertaining for students.

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