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Mobile Educational Application on Learning Electric Circuit for Primary School Using Augmented Reality

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Abstract: Electric circuits is one of the topics in Science which is being taught in year 2 primary school. However, most of the primary school lack of availability of laboratory and equipments for student to conduct experiments. The existing applications to learn electric circuit on Google Play are commonly not implemented with Augmented Reality (AR) and lack of learning module. Hence, mobile educational application on learning electric circuit using marker-based AR technology is developed on the Android platform to help user to explore the knowledge of electric circuit through an immersive environment. The user acceptance test has been conducted among 30 target users from SK Parit Raja. Positive results were obtained with an average of 69.13% strongly agreed and 28.54% agreed with the functionality and usefulness of the application. In conclusion, this application is appropriate for use as a teaching tool and learning medium for students to learn about electrical circuits.

Keywords: Mobile Educational Application, Electric Circuit, Augmented Reality

1. Introduction

Electricity is one of the topics in science that is being taught to Year 2 primary school students in Malaysia. In this topic, it discusses about the electrical components used in building a simple electric circuit, electrical conductors, and insulators objects. It is important for children to have a basic understanding on how electricity works which can help to keep them safe when using electrical objects [1]. However, traditional teaching method which are usually teacher-centered have been claimed to be ineffective in developing students' conceptual understanding [2]. The traditional teaching method are concentrated on "plug and play" method rather than practical aspects and the learning material usually only based on notes and textbooks [3]. However, this traditional method lack of interactivity and limited in delivering the concept of the topic to students [4]. Furthermore, the facilities of laboratory in most of the primary school are not well-equipped and insufficient for each of the students to conduct an experiment. Students absorb knowledge deeply when they learn through interactive, multisensory experiences, instead of only listening to somebody or reading textbooks. headings and sub-headings.

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Hence, applying technology like Augmented Reality (AR) feature in a learning application is a helpful tool to enhance the students' understanding.

AR is a technology that enhance the user's visualization by combining the real world with computer-generated objects to make the virtual items that appear to coexist in the same space as the real world [5]. By applying AR technology in the educational process, it is expected to provide alternative learning methods for students to learn which is more interactive and interesting [6]. AR technology is capable to transforming textbooks materials into 2D or 3D representations which can help to add some mystery and excitement to the learning process and motivate students to learn the new knowledges.

Currently, the existing Electric Circuit learning applications that are available in the Google Play Store only consists of one type of gameplay and the contents are not follow the syllabus of Ministry of Education Malaysia. Meanwhile, they also do not consist of learning module to help user learn step-by-step. In addition, the existing application also lack of implemented with AR technology to learn how a simple circuit works. Therefore, the mobile educational application, namely Mr. Electric Circuit is developed in this study.

The objectives of this study are to design the Mr. Electric circuit mobile learning application using visual learning approach, to develop an interactive learning application by implementing augmented reality technology, and to perform functional testing and user acceptance test on the developed application to the target user. The proposed application is developed for year 2 primary school students to learn the topic of electric circuit. The subject matter expert (SME) participating in this project is Puan Arneeda Bt Ahmad, who teaches Science subject at Sekolah Kebangsaan Parit Raja, Johor. Furthermore, the visual learning style implemented in this project focus on delivering contents through graphic materials. Mr. Electric Circuit can be used as an alternative learning tool for the school teachers to enhance the understanding of students for the topic of electricity.

The Mr. Electric Circuit mobile application consist of 2 modules which are learning module and mini game module. For learning module, it consists of three which are electrical components, electrical conductor and insulator, and simple circuit. AR technology is implemented in learning module to show the 3D model of electrical components and simple circuit with animation. For mini game module, it consists of three activities, which are find hidden object, quiz game, and electrical conductor and insulator. The challenges like life system, score and timer are included in mini game module. All interactive buttons in the application are expected to perform well. The learning module should display the right 3D model when user scan the AR marker.

The rest of the paper is organized as follows: Section 2 discusses the literature review of the related work and existing applications. Next, the methodology used to develop the application including the analysis and design is described in Section 3. Furthermore, Section 4 discusses the results and discussion, and Section 5 presents the conclusion of the project.

2. Related Work

In this section, the study domain, technology used, and result of the comparative analysis are discussed.

2.1 Electric Circuit

Electric Circuit is one of the subtopics consists in Year 2 primary school textbook in Unit 7 Electricity. In this topic, it discuss about the electrical components used in building a simple electric circuit, study how a simple circuit works and identify the electrical conductor and insulator objects. The aim of this topic is to deliver the knowledge of how a bulb can be lighten in a simple circuit. The current educational system was mostly based on the traditional teaching method. The learning materials are always used is a book, where all learning materials comes from the books which causes the students get bored easily

and difficult to understand the concept of the materials [7]. It becomes troublesome when teaching the topics involving abstract concepts especially Science subject. Primary school topics which consist of abstract concepts are challenging to teach [8].

Laboratory experiment plays an important role in supporting learning fields by enabling students to obtain practical skills through experiments and help them to have a deep understanding of the content [9]. However, most of the primary school lack of availability of laboratory and equipment for each of the students to conduct experiments. It causes some of the students have no chance to conduct experiment by themselves. This issue can be solved by applying augmented reality technology in the learning process which can transform the textbook materials into 3D representations. The next subsection explains the technology applied in the proposed application.

2.2 Technology Used

There are three technologies have been applied in this project. Firstly, Android technology which is the most popular mobile operating system in the world today. Based on the statistics conducted in 2022, it shows that Android operating system has been the dominant force in the global smartphone market which claiming more than 70 percent [9]. It is because Android is a free and open-source operating system which offers more freedom and customization options than iOS. It allows users to download any third-party resources to add additional features to their devices. Therefore, there is a wide range of applications which available in the market designed for Android devices.

Secondly, augmented reality (AR) is a popular technology that can combines virtual reality with reality. It allows overlaying of real-world objects and environments with 3D virtual objects using an AR device and allow the virtual objects to interact with the real-world objects. In recent years, AR technology has been widely used in many fields, such as tourism, art, education, commerce, entertainment, and leisure [10]. There is various game application implemented with augmented reality technology to provide immersive experience for the users. For example, Pokemon Go, which implemented with markerless AR technology where characters in the game can move around the environment, locate, and capture the Pokemon characters that pop up in the real world.

There are two different types of augmented reality which are marker-based AR and markerless AR. Markerless AR is a type of AR which does not require any physical markers to place objects in a real-world space and lets user to decide where to display the digital content [11]. Meanwhile, marker-based AR is a type of AR requires a trigger photo to activate the AR experience. Marker-based AR is perfect for first time user as it has very stable tracking and has a minimum production cost. Therefore, marker-based AR was implemented in this project.

Thirdly, visual learning style, which is one of the learning styles popularized by Neil D. Fleming in his VARK model in which information is presented to learner in a visual format [12]. Users could interpret information effectively through graphs, charts, maps, diagrams, and other forms of visual stimulation. In comparison to reading the text from the textbook, visual learning can help students to understand a complex topic better. Based on the studies, after three days, learners can retain 10-20% of information when written or spoken whereas 65% of visual information is retained [13]. It shows that visual learning can help to simplify the learning process and helps students to learn more effectively through graphic materials. Hence, visual learning style has been chosen in this project.

2.3 Comparative Analysis

In this section, a comparison has been made between existing applications, such as Electric Circuit AR [14], Electronic for Kids [15], Simple Circuit [16], and the proposed application. Figure 1 shows the main menu interface of the three existing applications. Meanwhile, 6 features have been discussed as shown in Table 1. It includes the operating system, content, augmented reality (AR), type of augmented reality (AR), module, and theme.

Figure 1(a): Electric Circuit AR [14]

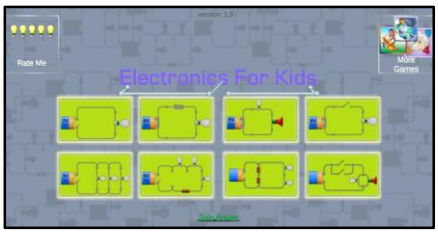


Figure 1(b): Electronic For Kids [15]

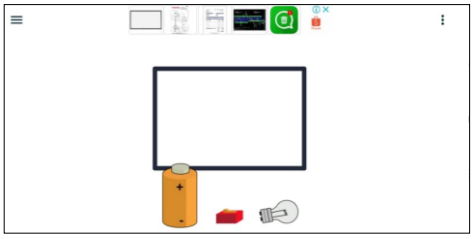


Figure 1(c): Electric Circuit AR [16]

Table 1: Comparison between existing applications and proposed applications

Features	Electric Circuit AR	Electronic For Kids	Simple Circuit	Mr. Electric Circuit
Operating System	Available for both iOS and Android system.	Only available for Android systems.		
Content	Electrical components, electric circuit, current and voltage, battery, LED, switch, resistor and resistance, electric circuit.	Parallel and series circuit.	Simple electric circuit.	Focus on Year 2 primary school textbook syllabus - Electrical components, simple circuit, electrical conductor, and insulator objects.
Augmented reality (AR)	Contain augmented reality technology.	Do not contain augmented reality technology.		Contain augmented reality technology.
Type of augmented reality (AR)	Marker-based	Non-AR (2D)	Non-AR (2D)	Marker-based and 2D
Module	Consists of learning module, quiz module, and one select and click game.	Consists of only one type of gameplay which is drag and drop.	Consists of only one type of gameplay which is drag and drop.	Consists of three learning modules, and three types of gameplays which are find hidden object, quiz game, and drag and drop game.
Theme	A yellow color theme.	A green color theme.	Do not apply any theme, only consist of white background.	A classroom theme, using green color as the main color for the main interface.

3. Methodology

The application, Mr. Electric Circuit, is a mobile educational application designed as an alternative learning medium to learn the topic of electric circuit. The Multimedia Mobile Content Development (MMCD) model is chosen to apply in this project because the project development process can be completed in a short duration of time and less problems that required to reconstruct. There are five phases consists in MMCD methodology which are application idea creation stage, structure analysis stage, process design stage, main function development stage and testing stage. Figure 2 shows the five phases of the MMCD methodology.

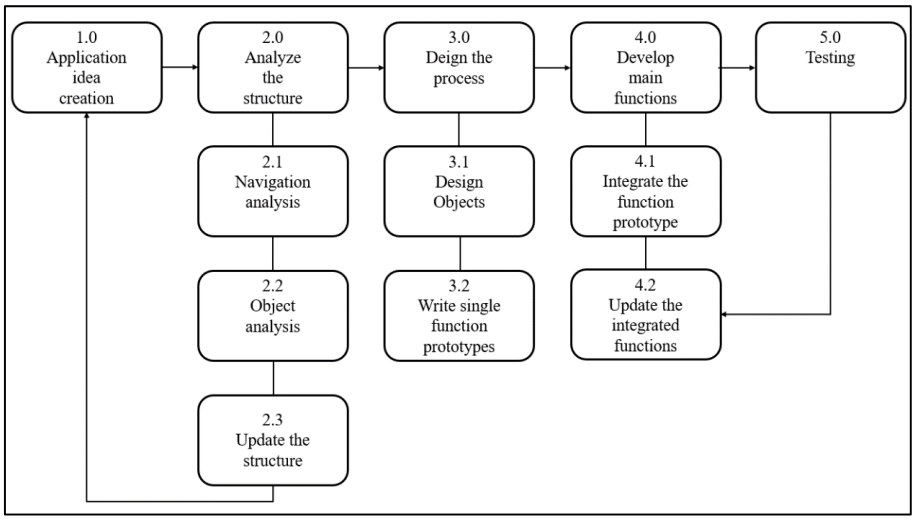


Figure 2: MMCD Methodology [17]

3.1 Application Idea Creation

The application idea creation stage is the first stage of MMCD methodology. In this stage, it is focusing on defining the information required for creating the electric circuit learning application for year 2 primary school students. The user requirements will be collected by performing a user analysis. An interview session was conducted with Subject Matter Expert (SME), which is a primary school science teacher named Puan Arneeda Bt Ahmad from Sekolah Kebangsaan Parit Raja, Johor. The interview is conducted online through the Google Meet platform. Open-ended questions are prepared to ask the SME during interview sessions to better understand the requirements of students in learning process and the importance of learning the topic of electric circuit. The results of the user analysis are tabulated in Table 2. Table 3 shows the application idea creation checklist.

Table 2: User Analysis

Stakeholder Category	Role in product	Design Implications	Action Needed
Subject Matter Expertise (Year 2 primary school science teacher)	Content consultant expert in related field	Based on the interview, Simple user interface design	• Instead of text, use icon-based buttons, which are easier for children to understand. • Use font type and sizes that are suitable and easier to read for children such as Comic Sans and Andika Bold with font size bigger than 35pt. • Use background images with vivid color.
		Easy Navigation	• All buttons are consistent in shape and size. • Apply universal icons for buttons such as home, setting, exit, back and volume.

Stakeholder Category	Role in product	Design Implications	Action Needed
			• The buttons should put at an appropriate position. For example, the quit button should be located at the bottom left corner while setting button should locate at bottom right corner.
		Easy to learn	• Clear instructions and narrator are given in mini game module.
		Reliable Content	• The content is designed based on the syllabus from Year 2 science textbook. • Use more graphical images to deliver the content instead of using text. • Use simple words which are easier to understand for primary school students.
		Clear Audio	• Provide clear audio narration before starting the game in mini-game module. • Consists of interesting background music to enable students learn in an attractive environment.

Table 3: Application Idea Creation Check List

Item	Description
Type of application	Mobile learning application
Target user	Year 2 primary school students
Target device	Android-based smartphone
Graphic User Interface (GUI)	Background of the main page, Module selection page, Learning module, Mini game module
Images	Background, buttons, icons, electrical components, game character
Audio	Background music, sound effect
Animation	To show how the electric current flows in a 3D model of a simple circuit.
Augmented Reality (AR) system	To show the 3D models of electrical components and simple circuit.
Application Synopsis	Mr. Electric Circuit is an AR-based mobile learning application for Year 2 primary school students in Malaysia. This application can be used as an alternative teaching tool for teachers and parents to enhance the understanding of students for the topic of electricity in science subject. There are various types of multimedia elements such as text, audio, graphics, and animation was implemented in the application to help students learn more effectively. The application is designed with two modules which are learning module (2D) and mini-game module (2D). The interactive AR module with 3D models is also included in the learning module.

3.2 Structure Analysis

Structure Analysis is the second stage of MMCD methodology. In this stage, there are two components will be analyzed, which are navigation analysis and object analysis. Figure 3 shows the navigation structure. Meanwhile, the content structure is attached in Appendix A. Functional and non-functional requirements are listed in Table 4 and Table 5.

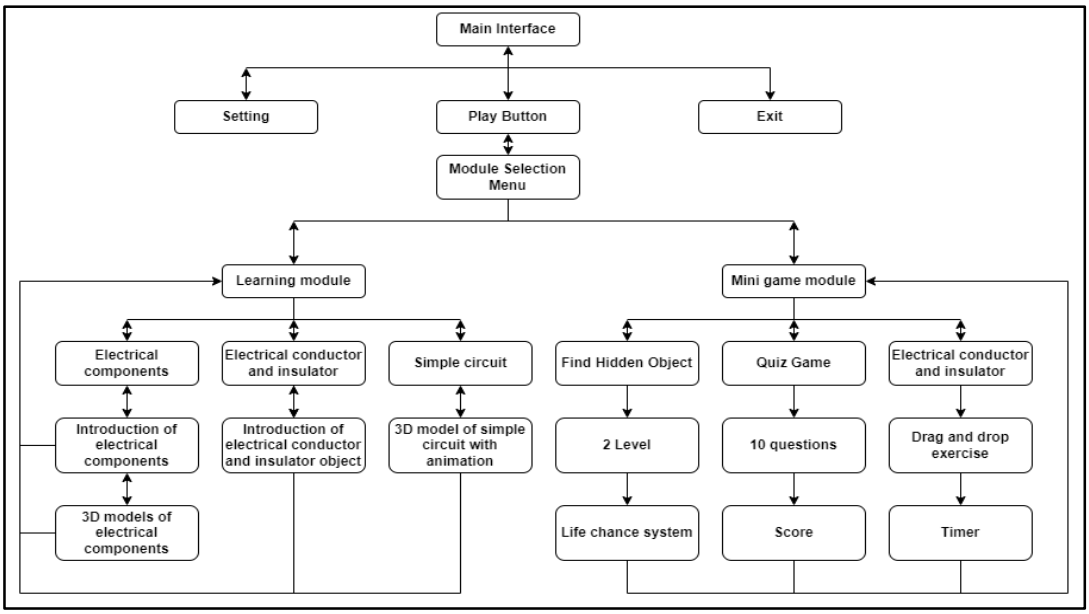


Figure 3: Navigation Structure

Table 4: Functional requirements

Functional Requirements	Descriptions
User interaction	• The system shall provide users with the ability to click the play button to start the application. • The system shall provide users with the ability to select modules. • The system shall provide users with the ability to click a button to scan the AR marker and view the 3D model of electrical components in the real-world environment. • The system shall provide users with the ability to click on the object in the find hidden object game scene. • The system shall provide users with the ability to answer the quiz by clicking on the button provided. • The system shall provide users with the ability to drag and drop the correct answer to the space provided.
Autonomous System Activities	• The system shall play the background music when user launch the application. • The system shall display the 3D model selected by the users. • The system shall display the 3D model with animation when user select the simple circuit learning module. • The system shall play the audio for the name and contents of the electrical components in learning module. • The system shall play the narration when user select and click on the start button in mini game module. • The system shall deduct the lives automatically when the users click on a wrong object in find hidden object game.

Functional Requirements	Descriptions
	• The system shall navigate user to the next question after finish answer a question. • The system shall calculate the score for the quiz game. • The system shall calculate the time for the gameplay. • The system shall provide the sound effect when the question is answered correctly or wrongly.
Provide learning content	• The system should allow users to learn the name and function of electrical components. • The system should allow users to learn how a simple electric circuit works. • The system should allow users to learn the electrical conductor and insulator objects.

Table 5: Non-functional requirements

Non-functional requirements	Descriptions
Performance	• The application shall be able to respond within 5 seconds for most of the Android mobile. • The time for the application to display the 3D model should within 3 seconds.
Operational	• The application shall be able to operate on any Android device with Android version 5.0 and above.
Cultural	• The application shall be developed in English. • The design theme shall be based on the school classroom environment.
Usability	• The application shall be user-friendly and easy to use and understand for the target users. • Users shall be able to access this application at anytime and anywhere with their Android mobile. • The application shall be able to provide enjoyable and immersive environment for users to learn.
Legal	• Users cannot modify any information displayed in the application.
Graphical User Interface Support	• The system shall be able to support all components of the application such as text, audio, graphics, animation, and 3D model on Android mobiles.

3.3 Process Design Stage

Process design was the third stage of MMCD methodology. The main purpose of this stage was to design all the components defined in structure analysis stage. In this stage, it consists of two sub-components, which are design objects and write single function prototype. At the end of this stage, the prototype of learning module and mini game module were developed. In this project, several types of authoring tools such as Adobe Photoshop, Adobe Illustrator, Canva and Procreate were used to design the storyboard, background, 2D images, game character, buttons, and AR marker. In addition, the 3D model of electrical components and simple circuit were designed by using Blender. Meanwhile, Unity software was used to develop the application by integrating the assets with scripting. Furthermore, the system flowchart was developed and shown in Figure 4. The remaining flowcharts of the mini game module were presented in Appendix B. Table 6 shows the button design, while Table 7 shows the interface design.

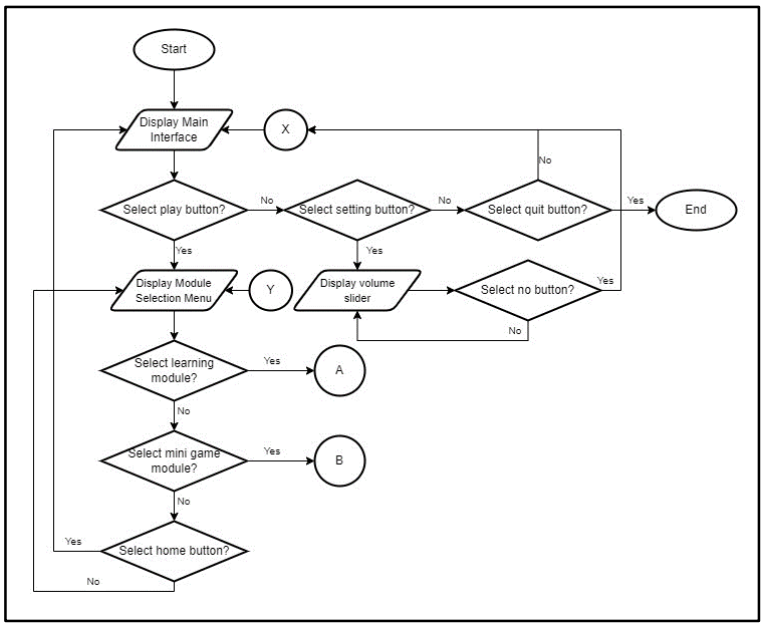


Figure 4: Main system flowchart

Table 6: Button Design

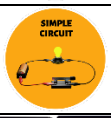
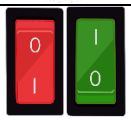
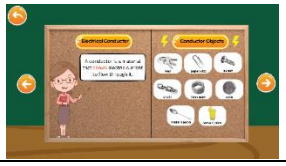
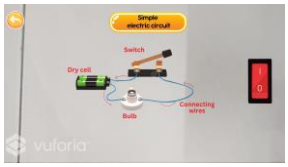
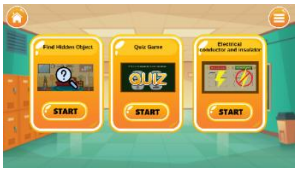
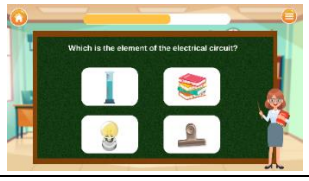
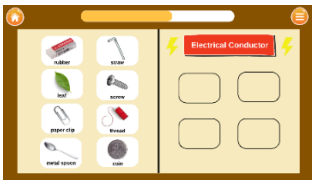
Button	Description	Button	Description
	• This is a start button.		• This is the home button.
	• This is an exit from game button.		• This is the menu button.
	• This is a setting button.		• This is the next button.
	• This is the close button.		• This is the previous button.
	• This is the skip and next level button.		• This is the info button.
	• This is the back button.		• This is the retry button.
	• This is the “yes” button.		• This is the view AR button.
	• This is the “no” button.		• This is the start game button.
	• This is the learning module selection button.		• This is the electrical conductor and insulator module selection button.
	• This is the game module selection button.		• This is the simple circuit module selection button.
	• This is the electrical components module selection button.		• This is the switch button which will show in AR scene.

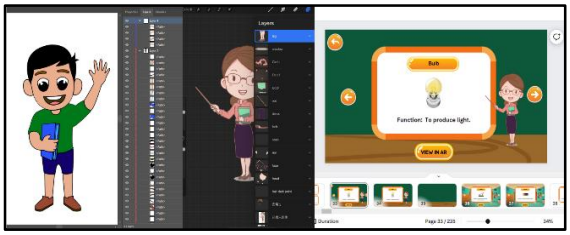
Table 7: Interface design

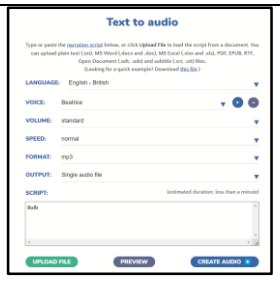
Interfaces	Description	Interfaces	Description
	This is the main interface of the application.		This is the electrical conductor and insulator learning module.
	This is the module selection page that contains two module buttons.		This is the simple circuit learning module with AR view.
	This is the learning module selection page that consists of three module buttons.		This is the find hidden object game module.
	This is the mini game module selection page that consists of three module buttons.		This is the quiz game module.
	This is the electrical components learning module.		This is the electrical conductor and insulator game module.

3.4 Main Function Development

Main function development is the fourth stage of MMCD methodology. There are two main activities included in this stage which are developing assets for the application and the integration of the assets into Unity software. There are four main elements developed as assets for this application. It includes graphics, 3D objects, animation, and audio, as tabulated in Table 8.

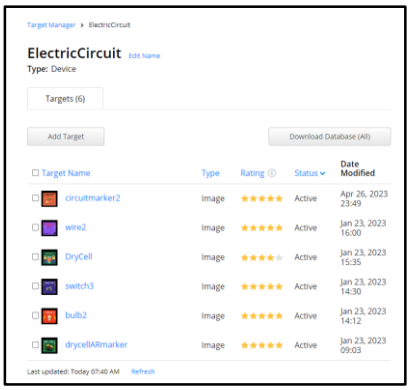
Table 8: Application Assets Development

Assets	Development	Description
Graphics		Adobe Photoshop, Adobe Illustrator and Procreate software were used to design the buttons and 2D images. The curvature tool and layer-based concept was applied to design the image. Brush tool "technical pen" in Procreate was used to draw the images. Designs are then imported into

Assets	Development	Description
		Canva to integrate with the elements from free resources and design the storyboard.
3D Objects		The 3D objects in the application were designed using Blender software. It includes electrical components such as bulb, switch, dry cell, connecting wires, and simple circuit. The editing tools such as extrusion, scaling and loop cut tool were utilized to shape and refine the mesh object. Then, the material was assigned to the 3D model to enhance the appearance of the 3D object.
2D Animation		2D animation such as animation of play button and hints were generated by create an animator and animation clip in Unity. The animation was then recorded by clicking on the keyframe recording mode button. The animation of star elements was created by using Particle System in Unity.
3D Animation		3D animation such as rotation animation of bulb and dry cell 3D models was generated by creating an animator and animation clip in Unity. For the open and close animation of switch 3D model was generated in Blender and import to Unity.
Audio		The audio files in the Mr. Electric Circuit application are in MP3 file format. It was generated using Narakeet, which is an online text to speech maker. This is to ensure the accuracy of the word and narration pronunciation.

In addition, the C# scripts are developed to implement the main functions in the application. It includes the database creation for target images, implementation of Augmented Reality (AR), interactive flashcards, matching the same objects, and generating quiz questions. The functions are explained in Table 9. In addition, the interfaces of the developed application are displayed in Table 10.

Table 9: Integration in Unity

Functions	Implementation and C# Scripts	Description
Create database and manage the target images for Augmented Reality (AR) function		The Vuforia engine software development kit (SDK) was selected to create Augmented Reality function in application. The Vuforia Engine version 9.8 package was downloaded from Vuforia Developer Portal and imported into Unity. A new database was created in Vuforia Developer Portal to upload the marker images. Therefore, Vuforia can detect the target image and overlay the virtual 3D models accurately on top of the real-world image.

Implements functionality in Augmented Reality (AR) scene (Electrical components and simple circuit learning modules)	`protected virtual void OnTrackingFound()`
	`{`
	`  if (mTrackableBehaviour)`
	`  {`
	`  var rendererComponents = mTrackableBehaviour.GetComponentsInChildren<Renderer>(true);`
	`  var colliderComponents = mTrackableBehaviour.GetComponentsInChildren<Collider>(true);`
	`  var canvasComponents = mTrackableBehaviour.GetComponentsInChildren<Canvas>(true);`
	`  foreach (var component in rendererComponents)`
	`  component.enabled = true;`
	`  foreach (var component in colliderComponents)`
	`  component.enabled = true;`
	`  foreach (var component in canvasComponents)`
	`  component.enabled = true;`
	`  }`
	`  if (OnTargetFound != null)`
	`  OnTargetFound.Invoke();`
	`}`
	`protected virtual void OnTrackingLost()`
	`{`
	`  if (mTrackableBehaviour)`
	`  {`
	`  var rendererComponents = mTrackableBehaviour.GetComponentsInChildren<Renderer>(true);`
	`  var colliderComponents = mTrackableBehaviour.GetComponentsInChildren<Collider>(true);`
	`  var canvasComponents = mTrackableBehaviour.GetComponentsInChildren<Canvas>(true);`
	`  foreach (var component in rendererComponents)`
	`  component.enabled = false;`
	`  foreach (var component in colliderComponents)`
	`  component.enabled = false;`
	`  foreach (var component in canvasComponents)`
	`  component.enabled = false;`
	`  }`
	`  if (OnTargetLost != null)`
	`  OnTargetLost.Invoke();`
	`}`
		The functionality in Augmented Reality scene such as showing the information panel when detecting the target image was handled using the default trackable event handler which is a pre-defined script in Vuforia. This script manages events like when a target is detected, lost or tracked. The `OnTrackingFound()` function displays the corresponding 3D model when the target image is found. Meanwhile, the `OnTrackingLost()` function deactivates the 3D model when the target image is undetected. For the interactivity functions with the 3D models such as switch on and off the bulb was controlled by using the built in `OnClick()` function.

Interactive Flashcards (Electrical components learning module)	`public void control (int i)`
	`{`
	`  number += i;`
	`  if(number > transform.childCount -1)`
	`  {`
	`  number = 0;`
	`  }`
	`  else if(number < 0)`
	`  {`
	`  number = transform.childCount - 1;`
	`  }`
	`  setActive();`
	`}`
	`public void setActive()`
	`{`
	`  for(int i=0; i < transform.childCount; i++)`
	`  {`
	`  transform.GetChild(i).gameObject.SetActive(false);`
	`  }`
	`  transform.GetChild(number).gameObject.SetActive(true);`
	`}`
		The `control()` function was implemented to change the content showing on the flashcard based on the integer variable `i`. If `i` is positive, then the number is incremented. If `i` is negative, then the number is decremented. If the number exceeds the index range of the child objects, then the contents of the flashcard will back to the beginning. In `setActive()` function, all the contents in the flashcard were inactive first by using `SetActive(false)`. After that, `SetActive(true)` was

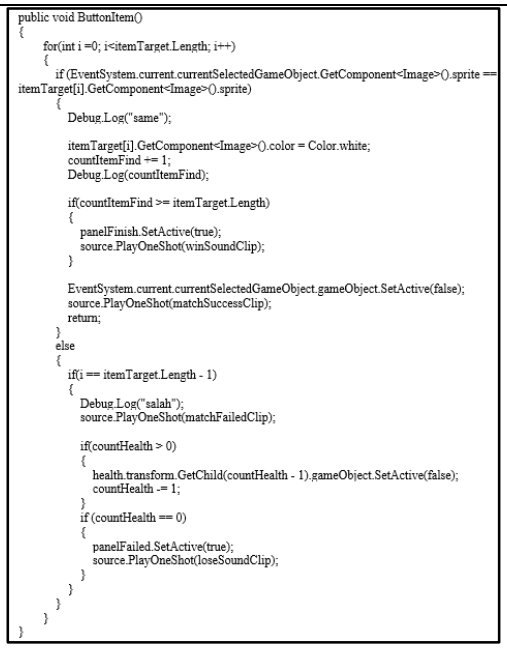
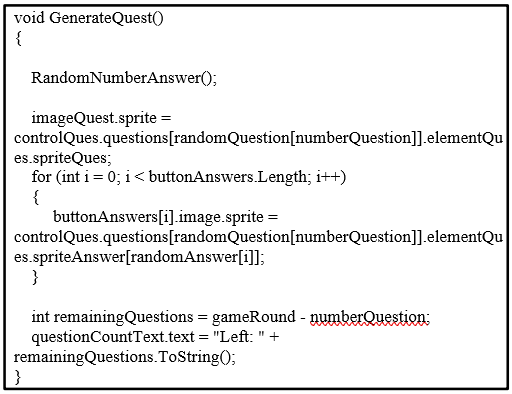
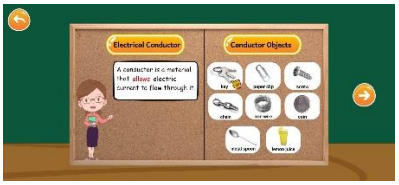
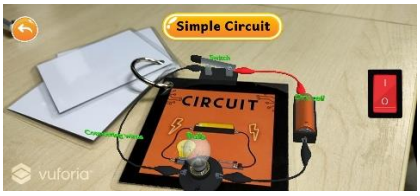
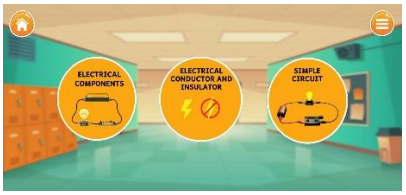
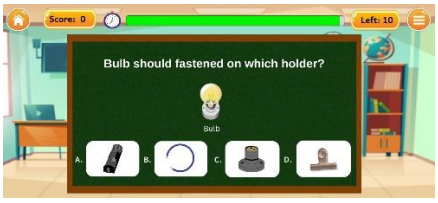
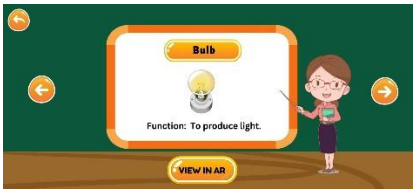
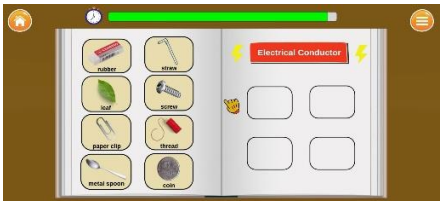
Functions	Implementation and C# Scripts	Description
		used to active the contents in the flashcard based on the number variable.
Matching the same object (Find Hidden Object game module)		The `ButtonItem()` function is called when an item in the scene is clicked. If the clicked item matches the target item, it will change the color of the image shown on the bar to white and update the `countItemFind` variable, increasing it by one. Additionally, the clicked item will disappear from the scene and the match success sound effect will be played. If the `countItemFind` variable more than or equal to the number of target item, the finish panel shown together with win sound effect. However, if the clicked item does not match the target item, the match fail sound effect will be played. Then, the `countHealth` variable will be decreased by one. If the number of `countHealth` reaches 0, the game will end and the fail panel will be displayed, together with lose sound effect.
Generate the quiz question (Quiz game module)		To generate a new question, sets the question image and assigns answer options to the buttons, the `GenerateQuest()` function was called. In this function, `imageQuest.sprite` was used to assign the sprite(image) for the question. Furthermore, the `remainingQuestions` variable was used to calculate the number of remaining questions and `questionCountText.text` is used to display the remaining number of questions in game interface.

Table 10: Interface of the developed application

Module	Interface	Module	Interface
Main interface		Electrical conductor and insulator learning module	
Module selection interface		Simple circuit learning module	
Learning module selection interface		Find hidden object game module	
Mini game module selection interface		Quiz game module	
Electrical components learning module		Electrical conductor and insulator game module	

3.5 Testing

Testing stage is the last stage of MMCD methodology. In this stage, it is focusing on testing the functionality of the application. Two types of testing, which are functional testing and user acceptance test have been performed to test and check whether the function of the proposed application meet the requirements and perform as expected. The project will return to the previous phase to update the integrated functions to fix the problems if bugs are discovered in this phase. The functional testing is presented in Table 11. The user acceptance test is discussed in Section 4.

Table 11: Functional Testing

Test	Expected Result	Actual Result	Corrective Action
Navigation Button	Navigates to different scene.	Works as expected.	Not required.
Exit button	Exit the application.		
Volume Slider	Adjust the volume of background music.		
Close button	Close the pop-up panel.		
Retry button	Retry the game.		
Augmented Reality Scene	Open the device's camera and allow user to scan the AR marker image.	Cannot access the mobile device's camera and it shows a black screen after clicking the button.	Replace the Vuforia engine from version 10.10.2 to version 9.8.13.
Skip button in instruction page of quiz game module	Start the game.	Occasionally, the button was not responsive when clicked.	The size of the text game object was adjusted to prevent it from overlapping with the skip button.
Life Chance System	Deduct one heart when clicking the wrong object. The game over panel is shown when both two hearts have been deducted.	The game still continues when two hearts have been deducted.	Add a new if statement `if(countHealth ==0)` in HiddenObject script
Sound Effect	The win panel was shown together with win sound effect when user finish answers the questions. Lose panel was shown together with game over sound effect if user lose the game.	The game over sound effects plays continuously with an echoing sound.	A boolean variable named `isRun` was initialized to stop the loop when the game has ended.
Score system in Electrical Conductor and Insulator Game Scene	Display win panel together with win sound effect when users finish dragging four objects to the drop area slot.	The win panel functions properly during the first time of playing. However, the win panel was not display when user replays the game.	`GameManager.Instance. ResetScore()` was initialized to reset the score when user replay the game.

Table 11 shows that a few errors were found. In Learning Module, the Augmented Reality (AR) was not functioning well as it cannot access the mobile device's camera. It is because the version of the Vuforia Engine 10.10.2 is unsupported on some devices. To ensure that the AR function can be accessed by most devices, Vuforia Engine Version 9.8.13 is utilized. Furthermore, the size of the text game object in the instruction scene is adjusted to prevent it from overlapping with the skip button and affect the function of the button. Additionally, an if statement, `if(countHealth == 0)` is used to overcome the problem of the life chance system. Furthermore, game over sound effects plays continuously when display the lose panel because the loop continues even after the game has ended. To solve this, a boolean

variable named `isRun` was initialized to stop the loop when the game has ended. Moreover, `GameManager.Instance.ResetScore()` was initialized to reset the score when user replay the game in Electrical Conductor and Insulator Game module. This was done to overcome the problem where the win panel was not shown when the user replayed the game.

4. Result and Discussion

This section presents data and analysis of user acceptance testing. The testing is conducted to evaluate the user acceptance of the developed application. Technology Acceptance Model (TAM) survey method is applied in this project. The application was distributed to Subject Matter Expert (SME) and target users which are 8 years old primary school student physically, along with a Google Form questionnaire. The questionnaire consists of four sections, which includes Perceived of Usefulness (PU), Perceived Ease of Use (PEOU), User Satisfaction (US) and Attribute of Usability (AU). Additionally, a 5-point Likert scale was applied to the questionnaire with options such as 'strongly disagree', 'disagree', 'neutral', 'agree' and 'strongly agree'. A total of 30 responses were collected and analyzed by using a bar chart.

According to Figure 5(a), there is an average of 79.98% respondents strongly agreed and 19.18% of respondents agreed that the content in the application is useful to enhance their understanding. The total percentage of strongly agreed and agreed are more than half. It indicates that the content of the Mr. Electric Circuit application is useful for users to enhance their understanding. Based on Figure5(b), an average of 41.1% of respondents strongly agreed and 52.23% of respondents agreed with the application's perceived ease of use. However, an average of 6.67% respondents remains neutral as they feel that the application is somewhat difficult to use, especially for the first-time users. It is because they do not know which AR marker images need to be scanned in the learning module.

Meanwhile, Figure 6(a) shows that an average of 70.66% respondents strongly agreed and 28% of respondents agreed that the Augmented Reality (AR) feature and interface design in the application is good and satisfied with the overall performance of the application. Furthermore, Figure 6(b) shows that an average of 84.76% respondents strongly agreed and an average of 14.76% agreed that the buttons, audios, animation, learning module and mini game module function works well. There is only an average of 0.47% respondents remains neutral due to the audio in the application not being clear. It is because the words pronunciation audio in learning module is short, and users need to replay several times to learn. In conclusion, the Mr. Electric Circuit mobile application has undergone user acceptance test and received positive responses from the intended users.

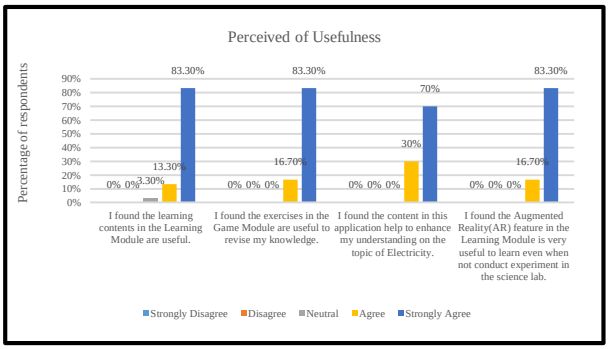


Figure 5(a): Analysis of Perceived of Usefulness

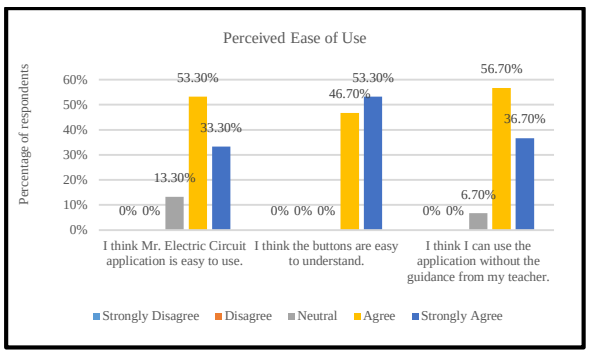


Figure 5(b): Analysis of Perceived Ease of Use

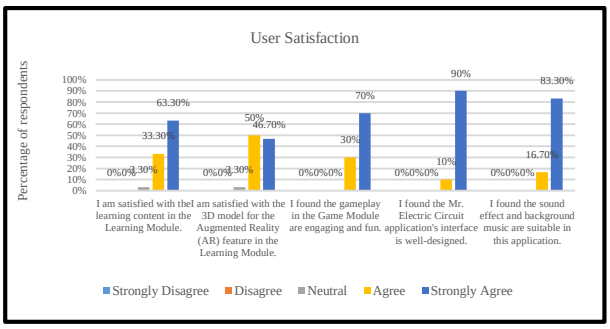


Figure 6(a): Analysis of User Satisfaction

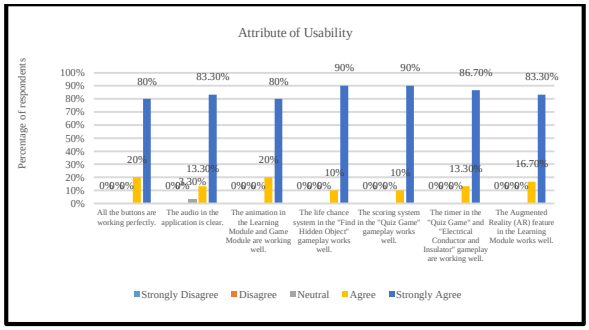


Figure 6(b): Analysis of Attribute of Usability

5. Conclusion

According to the results analyzed from the testing phase, the Mr. Electric Circuit mobile application is suitable for the target users to learn the knowledge of electric circuit through an immersive environment by implementing Augmented Reality (AR) technology. The three objectives of this project were successfully achieved by first designing a Mr. Electric Circuit mobile learning application using visual learning approach. Second, successfully develop an interactive learning application by implementing augmented reality technology. Lastly, perform functional testing and user acceptance test on the developed application to the target user when the application is finished developed. The Multimedia Mobile Content Development (MMCD) technology which was applied in this project helps this project to be completed on time. Furthermore, the advantages and limitations of the Mr. Electric Circuit mobile application are tabulated in Table 12. Lastly, for future works, it is suggested that more interactions can be added in the Augmented Reality (AR) scene which enables users to interact with the 3D models. Additionally, animations, such as the mouth and hand movements of a teacher character, can be incorporated to enhance the visual experience within the learning module. Moreover, more examples of electrical conductor and insulator objects can be added to the learning module. Furthermore, the number of levels in each game module can be increased to enhance user engagement.

Table 12: Advantages and Limitations of the Mr. Electric Circuit mobile application

Advantages	Limitations
• Provide useful 3D models of electrical components in learning module, which provides a more immersive and visually engaging learning experience for users.	• Provides only a few interactions for users to interact with the 3D model.
• The user interface is attractive and designed with good color combination.	• The user interface lack of animation.
• Consists of learning module for user to learn step by step before beginning the game module	• Provide only a few examples for the electrical conductor and insulator objects.
• Consists of three game modules for users to explore the knowledge of electric circuit.	• Provide only one to two levels for each game module.

Acknowledgment

The authors would like to thank the Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia for its support.

Appendix A

Appendix A presents the content structure in Section 3.2.

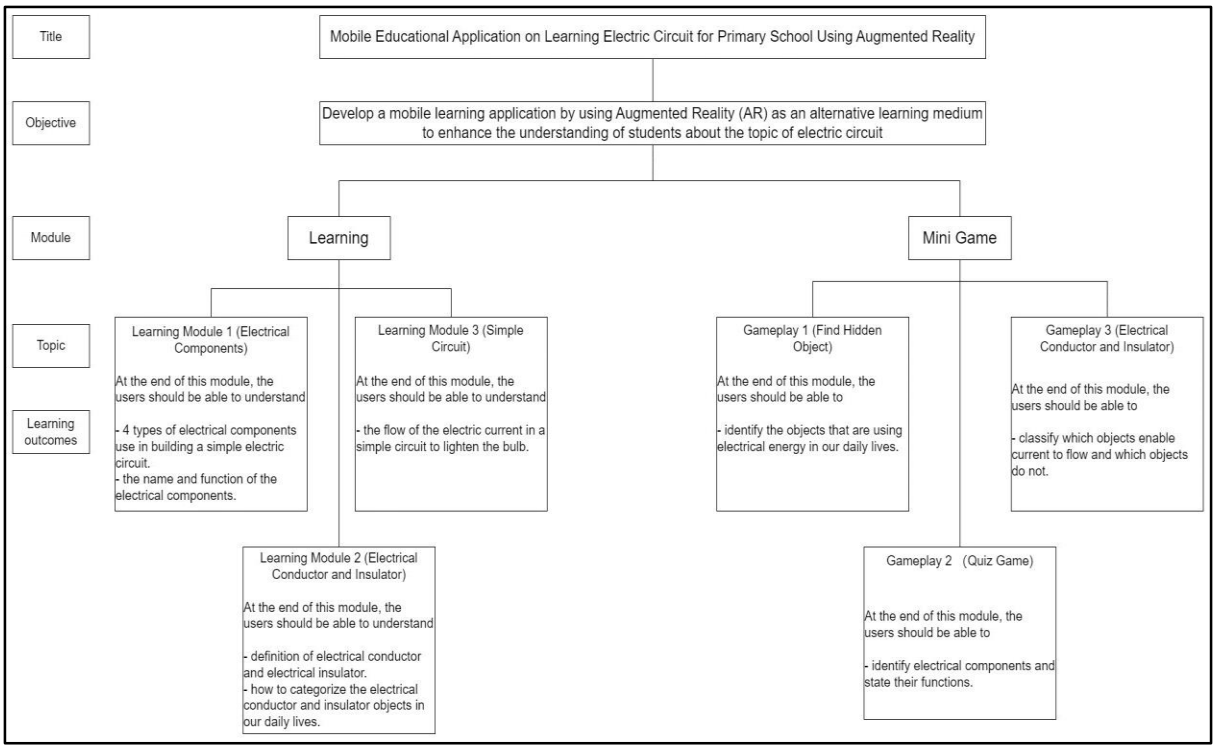


Figure 7: Content Structure

Appendix B

Appendix B presents the remaining flowchart in Section 3.3.

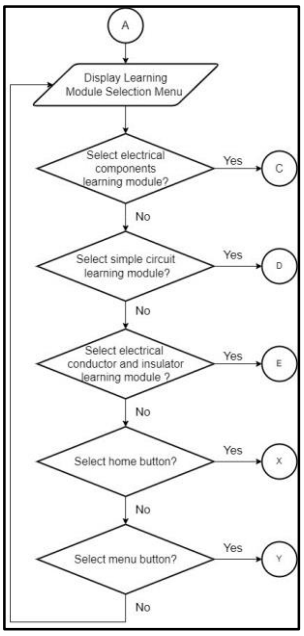


Figure 8(a): Learning module selection flowchart

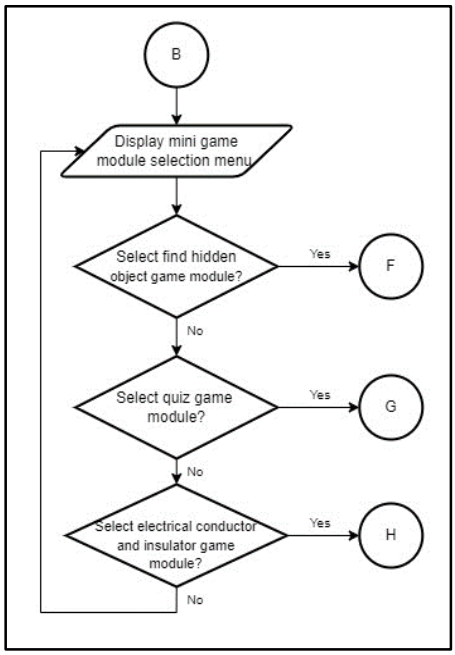


Figure 8(b): Mini game module selection flowchart

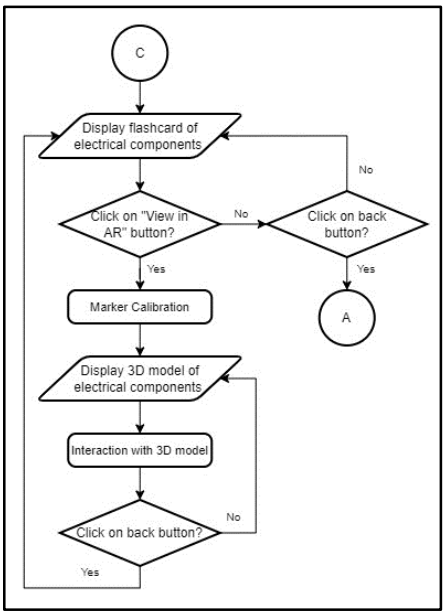


Figure 8(c): Electrical components learning module flowchart

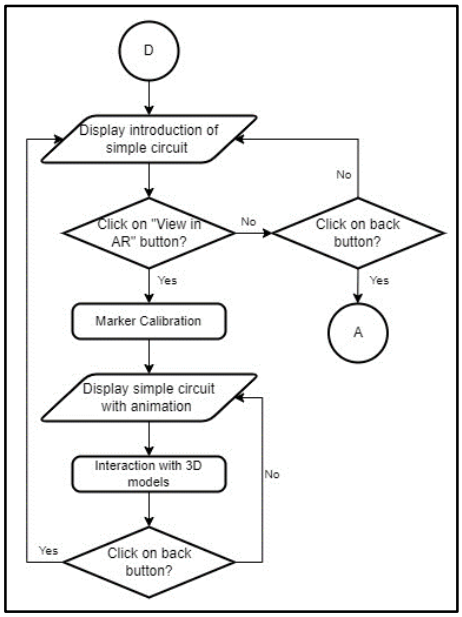


Figure 8(d): Simple circuit learning module flowchart

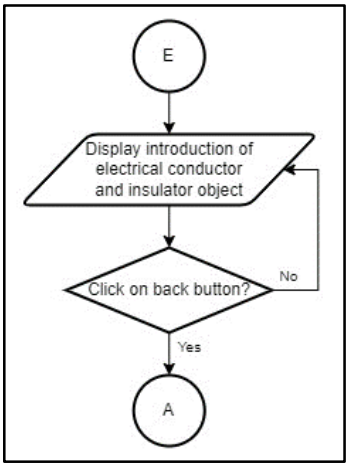


Figure 8(e): Electrical conductor and insulator learning module flowchart

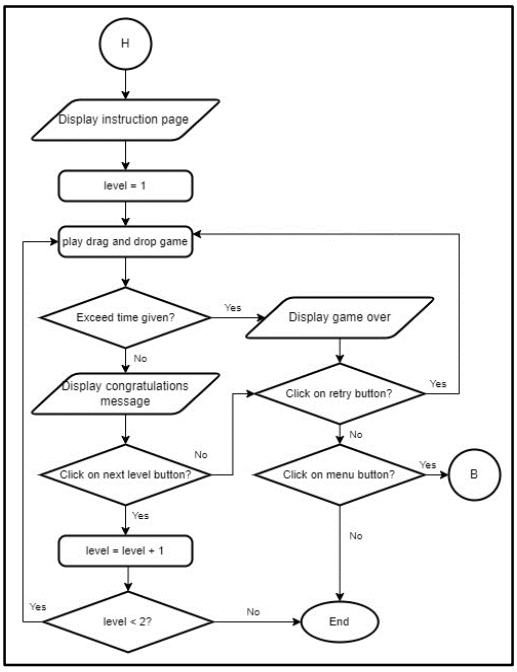


Figure 8(f): Electrical conductor and insulator game module

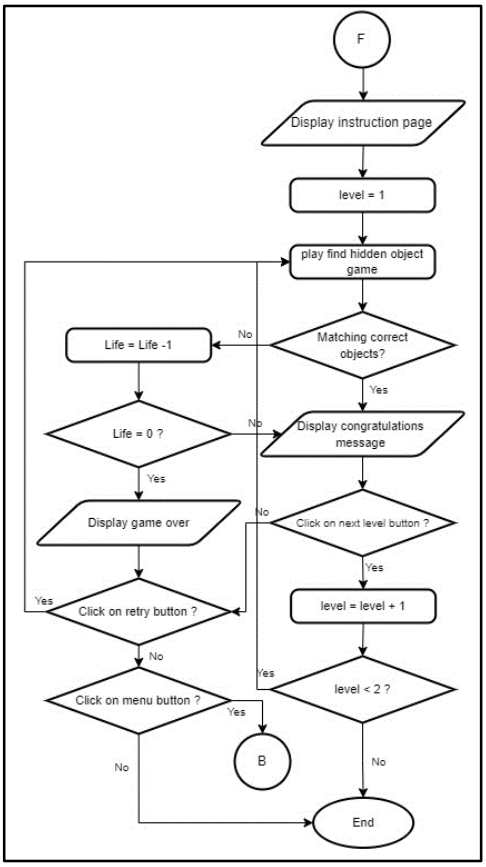


Figure 8(g): Find hidden object game module

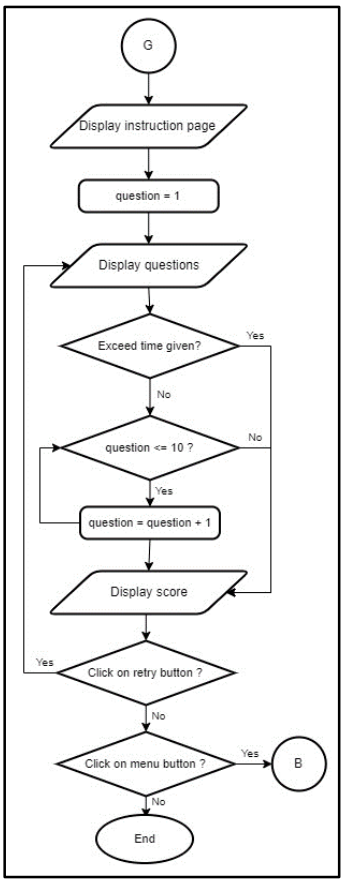


Figure 8(h): Quiz game module

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