Creating an AR application to help to learn to use electrical circuits using a breadboard

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Abstract

Augmented Reality in the field of education has been gaining more interest as the emerging technology keeps on evolving and becoming more accessible. The ability to use your phone as the device to view Augmented Reality, allows for more people to have access to the technology. This project is built to run on an Android mobile device and demonstrates how Augmented Reality can be used as a medium to help teach university students how to create electrical circuits on a breadboard.

A post-test questionnaire is used to help evaluate how effective the application was at guiding the students to creating a working electrical circuit. The project also shows how using an Augmented Reality application can help increase the motivation and productivity of the students.

Acknowledgements

First and foremost, I would like to thank my supervisor Dr Xi Guo as her supervision and guidance throughout the course of this year and the time at university has helped me succumb to new heights in my education. She has been giving me guidance to make the completion of this project come by so much smoother and to a higher level than what I could have done solely by myself.

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Glossary

|  |  |
| --- | --- |
| AR | Augmented Reality |
| LED | Light Emitting Diode |
| HMD | Head Mounted Displays |
| IMMS | Instructional Materials Motivation Survey |
| RE | Real Environments |
| RV | Reality-Virtuality |
| VE | Virtual Environments |
| VR | Virtual Reality |
| XR | Extended Reality |

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Word Count: 8230

# Introduction

This report aims to deliver a breakdown multiple research paper~~s~~ on how Augmented Reality can be used as a resource for university students to use to help them learn. This report will specifically be looking into how Augmented Reality can be used as a tool to help create electrical circuits on a breadboard.

## Problem Definition

When learning how to create a circuit using a breadboard, it can be difficult to ensure that the components you placed are in the correct position. A problem that was highlighted by a lecturer at my university was that students that were new to using a breadboard often found it hard to know where to put components and to know if what they were doing was correct. The aim is to create an application to help with this problem, by making it easier for students to know where to place the components on a breadboard.

## Scope

The project will focus on the creation of an AR (Augmented Reality) application that will help students create electrical circuits on a breadboard. Deliberation at the start of the project to include multiple electrical circuits which the user would follow had to be cut back due to the timescale to the project. This means the project only includes a single electrical circuit for the user to make, this circuit includes some of the key components of an electrical circuit: button, wires, LED, and resistor. This project is focused on the creation of the circuit on the breadboard and to guide the user where to place the components to create a working circuit. The project will not show the user how to connect the breadboard to an Arduino which would give the breadboard power.

## Rationale

This project’s main idea is to create an application with the ability to help teach using Augmented Reality. This will help the students feel more immersed in their work and will help them feel motivated, which will in turn encourage them to do more work on the subject. This will allow students to feel slightly more immersed with the teaching content. This project also aims to create an application which could be recommended by learning institutions as an additional resource teachers can have on hand to help them teach students how to create electrical circuits.

## Project Aim and Objectives

The aim of the project is to develop an AR application that will help university students create electrical circuits on a breadboard. The following objectives have been identified as aims that need to be accomplished over the development of the project.

* Investigate the current uses of AR in education.
* Investigate the different components in an electrical circuit for the application.
* Design and create an AR application for electrical circuits.
* Evaluate the effectiveness of the application to make improvements to it.
* Test the application with the target audience of university students.

The project does not show how to connect the breadboard to a power source whether this is a battery or connected into an Arduino. This project is to show and test the working of creating a circuit in the breadboard.

# Literature Review

## Literature Search Methodology

Search libraries used:

* Google scholar
* BCU digital library

Search terms used:

* Augmented Reality (AR)
* Virtual Reality (VR)
* Gamification
* Using AR for education
* Circuit breadboards
* Gamification for education

Above is a list of the key search terms used whilst searching for literature. During the search the papers had to be relevant with the focus on Augmented Reality, instead of Virtual Reality. The papers also needed to have had a reasonable number of citations on google scholar, where if it was above 100. AR is an emerging technology so when looking for papers of previous projects they had to been published after 2012, as this meant that they would be up to date. Some papers are older than this as they hold important information on the understanding of the technology and help to define what it is today.

## Themes

To work out what areas need to be researched key themes have been identified. These are: what is AR, the difference between AR and VR, AR in education, AR for circuits and Gamification. These themes are key to this project as the goal is to try and make an AR application to help educate about circuits. To do this, research into what AR is will help by giving a better understanding of how it works. Finding out about previous works that have tried to use AR for circuits will help identify strengths and weaknesses in approaches. Researching into how Gamification can be used will also improve the final product. These themes have some keywords related to them which are: Augmented Reality (AR), Virtual Reality (VR), Circuits, AR in education, Gamification.

## Theme 1 - What is AR? Difference between AR and VR

Azuma (1997) describes how “Augmented Reality (AR) is a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called.” This description of AR shows how AR can be seen as an alteration from a Virtual Environment. Azuma (1997) also defines AR as “systems that have the following three characteristics: 1) Combines real and virtual 2) Interactive in real time 3) Registered in 3-D”, using this definition of AR some forms of media are not counted as AR such as: a 2D overlay, as it is not 3D; or using virtual objects in a film, as this is not interactable in real time. This definition does include the use of see through Head Mounted displays (HMD), and monitor-based interfaces.

To help understand how AR and VR differ from each other Milgram and Colquhoun (1999) use the Reality-Virtuality (RV) Continuum shown in Figure 2-1, where “The portions of the illustration corresponding to the terms indicated will thus serve as our definitions of AR, AV and MR.”. The RV Continuum is used to show how there are 4 main types of RV. Where at the either ends of the spectrum are Real Environments (RE) and Virtual Environments (VE), between these there is mixed reality with both Augmented Reality (AR) and Augmented Virtuality (AV), where AR is closer to RE and AV is closer to VE. In this chart a VE is the equivalent to VR, which shows how VR and AR are on different ends of the RV Continuum.

Graphical user interface, text, application, email

Description automatically generated

Figure ‑: Definition of Augmented Reality, within the context of the Reality-Virtuality Continuum

Carmigniani and Furhy (2011) define AR using what was the Wikipedia definition at the time – “a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it.”. This describes how a key feature or AR is that it is a real environment that has had virtual components added into it. This highlights how AR aims to display virtual information to the users’ direct and indirect view of the real world around them to help simplify their life, whereas VR completely immerses the user in a fully synthetic world where they are unable to see the real world currently around them.

In the paper Yigitbas et al. (2022) a test is performed to compare AR and VR in a medical environment to train basic life support. The results show how AR and VR can both be used to help train in basic life support as both AR and VR produced very high training effectiveness. In the test scenario of giving CPR to a patient VR had a better presence score (the feeling of being of being in that situation), this is due to how VR fully immerses the user into a virtual environment, whereas when using AR you are still able to see your current surroundings, in the other scoring categories both AR and VR were closely matched to each other.

To summarize the papers a AR is a part of the RV Continuum, where it superimposes virtual aspects into a real environment during real time and the paper by Yigitbas et al. (2022) shows how both AR and VR can be used for training purposes, but if the goal of the training require the user to be in a specific environment, VR could be better as it allows for the creation of that environment.

### Theme 2 - AR In education

The emerging technology of AR has started its journey into the educational world as Jang et al. (2021) states how “educational researchers and practitioners have started to expect that emerging technologies such as Augmented Reality (AR) and Virtual Reality (VR) can bring new opportunities in educational settings”. This goes to show how education has a future where it uses AR and VR to be able to help teach and train students. This future still can seem distant as trying to implement using emerging technology such as AR is a significant change to the current methods used. The paper by Jang et al. (2021) shows that when teachers are aware of AR, they are able to see the advantages of using it in an educational environment.

Hsin-Kai et al (2022) mentions how an advantage of AR in education is “AR superimposing virtual objects or information onto physical objects or environments enables visualization of invisible concepts or events”. This would allow students to help understand how something works, that they might not normally be able to see, such as the internal components of a mechanism. This enhances the learning experience by using a visual perception of the educational content.

Hincapie et al. (2021) talks about how AR has the ability to benefit the teaching process, as it has the ability to promote kinaesthetic learning; allows students to be able to interpret and analyse 3D objects from differing angles and perspectives; AR increase the motivation and commitment the students have in the activities they need to complete; and it is a good way to be able to provide the students with contextual information relating to the learning activity. Hincapie et al. (2021) concludes that “The content-type defined as 3D models and animation has a better impact on memory and motivation than other content such as text, images, and videos.”.

Radu (2014) agrees that AR provides opportunities for teaching 3D spatial and kinaesthetic content and concluded that AR increases content understanding, long-term memory retention of the taught information, improved collaboration and found that AR gave an increase in student motivation. A problem with AR is that is does require the use of some device to be able to see the virtual components, due to this there will always be potential difficulties in using AR due to the hardware malfunctioning, or not being compatible. Radu (2014) also highlights some of the limitations of using AR, where AR would not be suitable to teach textual content or 2d simulations. Radu (2014) find that another major problem with AR is attention tunnelling – this is when students will miss out on some of the information in the virtual scene because they are too focused on a different part. This means that students must pay more attention to the lesson when it is being taught via AR. Even though students sometimes found the AR system harder to use then the pc alternatives, they were more enthusiastic about using AR.

The paper by Di Serio et al. (2013) uses The Instructional Materials Motivation Survey (IMMS) (Keller, 2010). This is a survey made up of many questions to work out whether the students found the use of AR motivational. By using 4 main factors. Attention, relevance, confidence and satisfaction. A lot of the papers have mentioned how using AR has increased student motivation, by using the IMMS as a template some questions and be created specifically to try and gauge if student motivation has been increased.

AR in education is still new in the field of education but there are promising signs of its success. Visualizing in 3D has been shown to help students understand the information that is being taught to them and AR is a very good way to give the student that 3D representation of the teaching information.

## Theme 3 - AR for Circuits

AR can be used, for many different applications. The paper Reyes-Aviles et al. (2018) shows a potential use of an AR mobile application. The project used an android mobile phone to house the application and uses a breadboard. The system uses AR to display the voltage and other information about the circuit, with the focus of identifying the resistors and how much resistance was in the circuit. The application used a marker-less system to track the breadboard location. A picture of the breadboard is taken, which then gets puts though a system to recognise where the different resistors are on the breadboard, after which the program identifies the resistors by scanning, the colour of the pixels. They project also had a short 6 question study, which showed that the AR application provided useful information.

Bellucci et al. (2018) compares the use of an AR mobile-based tool, 2d printed images, and the same images but on a monitor. The AR system that was used displays the instructions of where the student should place the electrical components to correctly make the circuit. To compare the different approaches, they measured the time it took participants to complete the circuit and the number of errors that they made. From the study AR can be seen to produce less errors; be easier to use; and was more useful. AR gave the participants more confidence in what they were doing because if they placed the component in the incorrect position, it would be clearer that it was in the wrong place due to the AR displaying the correct positions.

The project Pérez et al. (2022) created an application that was able to be downloaded through an APK. The used QR codes to present some of the information to the students. Inside the app the user was also able to press different buttons, that allowed them to switch between the different steps of creating the circuit. In each step there were animations showing the different components being placed in the correct positions. The overall results from the study were successful as the project was able to increase retention of the activities carried out. The project was so successful it encouraged the possibility to add more parts of the main course into an AR learning experience.

The system Reyes-Aviles et al. (2018) made worked very nicely at working out where a resistor is on a circuit and identifying it, but this system does not help the user in any way to place the resistors in the correct place. Bellucci et al. (2018) shows how learning from AR has great potential as students made less mistakes when using the AR system and Pérez et al. (2022) shows how teaching using AR can increase the amount of information that the students retain. These show how teaching circuits using AR can create a more productive learning environment than traditional methods.

## Theme 4 - Gamification

Dererding et al. (2011) defines gamification as “the use of game design elements in nongame contexts”. This is shown clearer by Marti-Parreno et al. (2016) who created a tree to demonstrate the different sections of game based learning Figure 2-2. The diagram clearly shows how gamification is separated from the games, as gamification is using the game design and game elements in a non-game context as opposed to directly creating a game.

Diagram

Description automatically generated

Figure ‑: Marti-Parreno et al. (2016) Typology of Ludification of Education

The paper by Seaborn et al. (2015) is a survey of existing literature on gamification. What they concluded were the main key game elements used in gamification shown in Table 2-1. Seaborn et al. (2015) continues by stating that gamification “has two key ingredients: it is used for non-entertainment purposes, and it draws inspiration from games, particularly the elements that make up games”, this agrees with the previous definition of gamification, but adds how it is used for non-entertainment purposes. This emphasises how the use of gamification is not the act of creating a game but the use of game features, such as the one in Table 2-1. Seaborn et al. (2015) also concluded that “pointsification” – the use of points, badges, and leaderboards – is used within most gamification strategies.

*Table 2-1: Legend of game element terminology*

Graphical user interface, text, application

Description automatically generated

Kiryakova (2014) comes to the conclusion that “Gamification is an effective approach to make positive change in students’ behavior and attitude towards learning, to improve their motivation and engagement.” This demonstrates how gamification can be a useful tool to help students engage in the tasks that they need to complete. This compliments the definition given by Kapp (2012) gamification is “using game-based mechanics, aesthetics and game thinking to engage people, motivate action, promote learning, and solve problems”.

In summary gamification is using game based features such as: points, badges, and leaderboards, for a product that is not a game. The use of gamification has been shown to have positive impacts on the motivation and engagement of students, but it can be hard to tell if gamification is effective or not, as Seaborn et al. (2015) found the results to be very mixed. Overall there tends to be a positive trend with the use of gamification and motivation of students, but this does not always tie into better grades.

## Summary

The summary of the papers that have been read is as follows. AR is an emerging technology that is finding its way into the educational field. AR can be defined as a technology that superimposes virtual components into a real environment during real time. The virtual components added can provide extra information and details about what the user is looking at. In practical use of using AR and circuits, AR can be used to display helpful information such as the voltage and resistance as well as its ability to give instructions to the students that can be clearer and easier to follow. Gamification is a process of adding game elements into a non-game context, this tends to increase the student motivation and engagement for the activity that they are performing. From this I can conclude that I want to use AR to help teach how to create a circuit on a breadboard. The app will also try to use some features of gamification, to make the app more appealing to students.

# Method and Implementation

## Introduction

This section of the report outlines what development methodology the project will use, some of the limitations and challenges that the project will have and how to overcome them. The design of the project and how the user will interact with the application as well as details in the learning content are described in the concept solution, and design and development sections. How the solution of the project will be tested is also described in the testing section.

## Methodology

There are quite a few different Software Development Life Cycles (SDLC) which define the framework for how the project will be completed. Some of these include: Waterfall, Agile, and Spiral. This project will be using the Agile methodology.

The advantage of using an Agile methodology is that it is a very realistic approach to how software development takes place. The resources needed for an Agile methodology are small which will work well as a single person is working on the project. The Agile methodology works in iterations which allows for flexibility of the project. Agile will also create a base application faster allowing for changes to be made earlier to help to improve it.

## Limitations and Options

One of the first limitations is about how to use AR. In 2023 the best AR Glasses described by Software Testing Help (2023), are all very expensive, for example the Oculus Quest 2 costs $399. The costs of these devices are too high for this project. If the project relied on the use of one of these devices it would also make the application less available for students to use, as they would need to own the device. The solution to this problem is to design the application for handheld devices. This will mean that there will be no cost involved to acquire a device to display the AR, and as 96% of 16-24 year olds in 2021 owned a smartphone – Hiley (2022), the application will be available to most students. For this project the application will be designed for android devices, but if it is successful a version of the application can be designed to support other mobile devices as well.

A major limitation of this project is the time restraint and that only one person is creating the application. This means that the application will not be able to be fully fleshed out in every aspect. The main purpose of the app is to help learn circuits on a circuit board but due to the time limitation mentioned above the app will only contain one example for the user to follow. This example is described in more detail later in the report.

A limitation of this project is the ability to track the location of the breadboard, this is a key element of the solution, because if the application does not know where the breadboard is located then it will not be able to place the virtual AR components in the correct place Reyes-Aviles et al. (2018) uses a marker less system to track and identify the breadboard and elements on it. This solution looks like it might work with the application that would need to be made, there is a much simpler solution, which should have a smaller margin of error. This solution is to use QR codes that the application can track and then place the virtual component based on the positioning of the QR code.

## Design Specification/User Requirements

The hardware for this project will be an android device which will have the application downloaded onto it. The user will also need a breadboard with the appropriate QR code on it for the app to identify its position. Specific electrical components will also be needed which include: a 4-pronged button, a resistor, a LED, 5 wires to connect the different components and an arduino.

## Development of the application

### Initial Design

This project aims to develop an application to help teach how to use a breadboard, and where to place the components on it. The application aims to have one example for users to follow. The image in Figure 3-1 shows the design of the circuit that will be made on the breadboard, the design was made using Tinkercad. The application will be available to download onto android devices.

A picture containing text, electronics

Description automatically generated

Figure ‑: The design of the learning content

When the user opens up the app, they will be prompted to select which example they want to follow, for this project there will only be one, but this will allow for more examples to be added into the application in the future. After they selected which example they want to do, the user will be able to point their phone towards the breadboard to scan the QR code, as seen in Figure 3-2.

Diagram

Description automatically generated

Figure ‑: Initial design of the main screen the user will see when using the application.

After the user has scanned the QR code the first step will start and will display to the user where the first components should go on the breadboard. An animation will display the virtual objects above the position they need to be placed into. The user is then able to control from the buttons at the bottom of the screen when to go to the next step and when to play and pause the animation.

The app was made using the Unity game engine as this will allow for easier and faster creation of a mobile application. Using the Unity game engine will also make some of the key tasks easier, such as creating animations and effects to display in AR. The app will have the base AR system of AR Core which is the main system used to create AR applications in Unity.

The application was broken down into smaller steps which show how the user would be able to interact with the application which is displayed in Figure 3-3, as well as the steps that the user would take to get through the application from the start screen. A diagram to show the different steps that would need to be implemented for a user to create the desired electrical circuit is displayed in Figure 3-4.

Diagram, table

Description automatically generated

Figure ‑: Flow diagram showing how the user interacts with the application.

Diagram

Description automatically generated

Figure ‑: Steps to complete the example.

### Development of the application

The starting task to creating the application was to create and set up a project inside of the game engine unity. This project had the ability to display 3D models, as this was necessary to display the models in AR. Inside of unity the AR foundation and ARCore XR Plugin were installed. These packages add the ability to easily create AR objects. The package comes with an AR Tracked Image Manager script, which allows for an image to be added for the program to track. By using a QR code as the tracked image it will ensure that no matter what angle or rotation the image is the displayed AR object will always be in the same orientation in comparison to the QR code. The image in Figure 3-5 below shows how the QR code was attached to the breadboard which allows it to be tracked.

A close-up of a circuit board

Description automatically generated with medium confidence

Figure ‑: Picture of the breadboard with a QR code on it.

### Getting models for the application

The project required certain 3D models to be displayed in the AR environment, these 3D models included: a breadboard, an LED, a resister, a button, and some wires. Models for some of the components were sourced from Sketchfab. The main breadboard model was made by Matys. (2018), the LED that is used in the project is made by sas111. (2017) and the resistor that model that was made by Tsuica. (2022). The 3D models of the button and wires were made using Maya 2023, over multiple iterations to ensure that the components lined up correctly with the breadboard model. The collection of models, both the models sourced from Sketchfab and ones created in Maya 2023, were then imported into the Unity game engine. The models were then arranged according to the design of learning content which had been created previously, below Figure 3-6 shows the 3D models inside of unity.

Calendar

Description automatically generated

Figure ‑: Picture taken showing the 3D models inside of a unity screen.

### Putting models in AR

With the 3D models implemented into the Unity project, the next stage is to display these models in AR. This process seemed simple, but ended up requiring more time and problem solving than was first expected. This meant that it added a delay to the whole schedule of the project. To display the 3D models in the AR space around the real breadboard only required the use of the QR code and the AR Tracked Image Manager Script which is part of the AR Foundation package. The problem to the system came when trying to gain access to the instantiated model. Getting access to the model after it was created in the AR space is essential, because the components that were making up the 3D model being displayed needed to be enabled and disabled to show the different stages that were required in creating the electrical circuit. To solve the problem a prefab that contains all the models was created, this prefab is what gets instantiated when the app is pointed towards the QR code. To get access to this prefab, it was assigned a unique tag and a script was created to look for a game object with that tag on it once found it will save the prefab to a variable. This system allowed access to all the different models that needed to be instantiated.

### Adding guidelines

The next part to add into the system was to create guidelines and animations to aid the user in placing the electrical components into the correct position on the breadboard. The goal of the animation is for it to be a guide for the user to follow placing the component into the breadboard, where the guidelines improve the visibility to ensure that the component is placed in the correct position. The guidelines created a dotted line from the bottom of the different electrical components and went into the breadboard, to highlight the exact positioning where they are meant to go, Figure 3-7 shows all the different guidelines of the models and Figure 3-8 shows what the user would see as they can only see one guideline at a time. The line was made up of individual small cylinders with different materials on which allowed for the guideline to slowly fade from opaque to transparent. To create and control the animations the Animator was used which is pre-built into the unity game engine.

A picture containing calendar

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Figure ‑: Image showing all the guidelines.

Calendar

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Figure ‑: Image showing only the guidelines of the LED.

### Creating the UI

The initial UI for the screen which displays the AR elements, was based on the initial design in Figure 3-2. The image below in Figure 3-9 shows the design which was created. The design has a big indicator in the middle of the screen to tell the user that they need to point the phone towards the QR code which will then allow them to see the AR breadboard, this text will promptly disappear once the user has looked at the QR code to indicate that the app has recognised the QR code. The settings button which was in the initial design was not a necessity to make the application run so it was excluded from the UI to allow for more space on the screen for the user to see the augmented objects.

Graphical user interface, text, application, chat or text message

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Figure ‑: Image showing the design of the UI when the user id using the application.

## Improvements to the application

This project was using an agile methodology and had two main phases. After the first development cycle a test was conducted with a small group of university students to test the application. After completing the tests numerous problems were highlighted in the design of the application so changes were made to try and apprehend these problems. The results of these test and more detail on them are section 4.2 Results and section 4.3 Discussion.

### Improve the graphics of the breadboard

The most obvious issue that was repeated by most of the testers was how they would all place the electrical components on the non-intended side of the breadboard. This would mean that the circuit would not properly power so would not work even if the components were in the correct positions. This issue also lead to a lot of confusion from some of the participants as this issue meant that the AR model which they were following no longer completely matched up with where they were placing the components. The reason this issue happened was due to some of the number and lettering on the virtual breadboard not matching up with real breadboard in front of them. To solve this the texture which had been applied to the breadboard model was modified inside of Photoshop to match the look of the real breadboard.

### Added feature - scale AR models

The feature to scale the size of the AR model was added into the application to add additional accessibility. This feature allows the user to increase or decrease the size of the AR models by using a slider on the right-hand side of the screen as shown in Figure 3-10. The scale feature was added directly to the UI of the screen rather than hiding it in a settings menu, because it allows the user to easily see the AR model scale in real time whilst they move the slider. The ability to scale the model makes it easier to see and understand where the electrical component is meant to go on the breadboard.

Graphical user interface, application

Description automatically generated

Figure ‑: Image showing the UI of the scale feature.

### Added Feature - tutorial text

This added feature displays a small amount of text on the left-hand side of the screen to help the users complete the circuit, Figure 3-11 shows the UI component. This feature was not originally intended to be a part of the application, but after the test it was shown that some small level of additional information was needed to be given to the users to help them create the intended circuit. The main issue this text box is meant to resolve is that users would frequently place the LED component in the incorrect rotation which meant that the circuit would not work. Adding in the text box also fixed an issue where after the user had scanned the QR code they did not realise that the virtual breadboard had spawned in, so the text told the user that it had spawned and to move their phone slightly away from the QR code which enabled them to see the breadboard without any external help.

Graphical user interface, application

Description automatically generated

Figure ‑: Picture showing the UI of tutorial text box

This feature also has the potential to be used to a greater extent in the future of this application. The circuit which the users had to make in the tests was a more beginner level circuit, but the application has the potential to help teach more complex circuits with a greater number of components making it up, here the addition of the text box will give more information to the user to help them understand and complete the circuits.

# Evaluation

## Evaluation Methodology

To evaluate how effective the product was the participants were required to answer a questionnaire after they had tried the application. The breadboard and the different components needed to complete the exercise on the app was provided to the students. At the start of testing the students were given a brief introduction to inform them about the AR application and how their goal is to create a circuit using the application to help them. After they had used the application, they were given the opportunity to fill out a questionnaire to assess how effective the application was. The questionnaire had questions to ascertain how successful the application was at helping the students create the circuit, some of the questions were also based off the questions in the UTAUT for acceptance of mobile learning among students and teachers.

### Evaluation Metrics

The three metrics which are being used to assess whether the application was a success or a failure are:

* If the student felt more confident in their knowledge of circuits after using the application.
* If the student was able to create the circuit using the application and get it working.
* If the student felt confident that they could recreate the circuit without the application

### Dataset

The project is using an agile methodology there where two tests done on different versions of the application, the first test consisted of 7 participants and the second test consisted of 13 participants. The second test consists of the 7 participants who were a part of the first test.

## Results

The following section will include graphs to show the results to the questionnaires which were taken after both tests to show the difference between the answers received from the first test to the answers received in the second test. The graphs below show the answers to the questions where the students had to rate from 1-5 if they agree with the statement, where 1 is that they don’t agree and 5 is that they agree.

### How useful the application is for work

Chart, waterfall chart

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Figure ‑: Bar Chart showing the response to I would find the application useful for work from the first testing group.

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to I would use the application for my learning from the first testing group.

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to I would find the application useful for work from the second testing group.

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to I would use the application for my learning from the second testing group.

The above questions are key to try and understand whether the students would use the application. The results from both the first test and the second test show a very strong positive trend towards agreeing with the statements. This shows that the project is successful in creating an application which students will want to use as part of their learning experience. There are also not any significant changes between the results of the first test and the second test which shows that the base model of an application using AR to help teach AR is very likely to be used by students.

### Increase productivity and make work more interesting

Chart

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Figure ‑: Bar Chart showing the response to using the application increases my productivity from the first testing group.

A picture containing chart

Description automatically generated

Figure ‑: Bar Chart showing the response to the application makes the work more interesting from the first testing group.

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to using the application increases my productivity from the first testing group.

Chart

Description automatically generated

Figure ‑: Bar Chart showing the response to the application makes the work more interesting from the first testing group.

These questions are trying to gain from the students whether the application helps them to find the work interesting and helps to increases their productivity. These two values are normally highly linked together, because if you are more interested in a subject, you are more likely to want to do that subject. The results from the questionnaire reflect this very well as the students agreed that the application help to increase both their productivity towards the work and their interest in that work.

### Confidence in making circuits before vs after

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to how confident are you in your knowledge of circuits before you used the application from the first testing group.

Chart, bar chart

Description automatically generated

Figure ‑: Bar Chart showing the response to how confident are you in your knowledge of circuits after you used the application from the first testing group.

Chart, bar chart

Description automatically generated

Figure ‑: Bar Chart showing the response to how confident are you in your knowledge of circuits before you used the application from the second testing group.

Chart

Description automatically generated

Figure ‑:Bar Chart showing the response to how confident are you in your knowledge of circuits after you used the application from the second testing group.

The questions above in Figure 4-9 to Figure 4-12, show key information to show whether this project can be called a success and how successful of a project it is. The application is meant to be used to help teach students how to use circuits, so if after using the application they felt less confident in circuits or only improved by a small margin the project was not successful. The data collected from the students shows that after both the first and second test the average knowledge of circuits increased. In the second test there was a higher number of students who felt confident in their knowledge before starting the test, this could be due to the larger sample size, but it could also be because the students who participated in the first test where also allowed to participate in the second test meaning that they would have more knowledge about circuits from the first time they use the application.

### Confidence to recreate the circuit, how easy it is to become good at using the application.

Chart, bar chart

Description automatically generated

Figure ‑: Bar Chart showing the response to how confident are you that you could re-make the circuit without the application from the first testing group.

Chart, waterfall chart

Description automatically generated

Figure ‑: Bar Chart showing the response to it will be easy for me to become good at using the application from the first testing group.

Chart, bar chart

Description automatically generated

Figure ‑: Bar Chart showing the response to how confident are you that you could re-make the circuit without the application from the second testing group.

Chart

Description automatically generated

Figure ‑: Bar Chart showing the response to it will be easy for me to become good at using the application from the second testing group.

The results to the questions above highlight a very big issue currently with the application, the problem is that students don’t feel that confident in their ability to remake the circuit without the application. This is a major problem with the application as it is meant to help teach the students how to make the circuits. This problem is an aspect which will need to be improved in the application, because if the students don’t end up retaining the information that they learn from using the application it will not end up helping them to get better and learn more about circuits. This problem could be resolved by having different modes in the application. The modes could be one which acts a tutorial guiding the student step by step, which is what the current application does. The other mode can be a system where the user must put components into the circuit first and can then check to see if they placed it correctly.

In opposition to the students not being able to recreate the circuits, the students find that the application is easy for them to become good at. This shows how the use of an AR system to display information to help the students learn is easy for them to grasp. Due to the application being easy to become good at using, as students become better at using the application in company with more circuits being added into the application in the future students might retain more of the information that they learn from using it.

### I got the circuit to work

Chart, pie chart

Description automatically generated

Figure ‑: Pie Chart showing the response to I got the circuit to work from the first testing group.

Chart, pie chart

Description automatically generated

Figure ‑: Pie Chart showing the response to I got the circuit to work from the second testing group.

The key indicator to show how successful the application is at helping students to create an electrical circuit, is whether the student was able to create a working circuit from using the app. The results from the first test show that over 50% of the students were unable to create a working circuit and only 42.9% of the students could create a working circuit with 14.3% making the circuit correctly first try. In the second test only 7.7% of students could not create a working circuit with 92.4% of students able to create a working circuit using the application. This is a very significant difference between the first test and the second test showing how the changes that had been made to the application had a major weight in how effective the application was in helping the students to create a working electrical circuit.

## Discussion

The results from the questionnaire agree with the paper by Hincapie et al. (2021) who concludes that “The content-type defined as 3D models and animation has a better impact on memory and motivation than other content such as text, images, and videos.”. This is shown by 85% of the participants of the second test finding that using the application helped to increase how interesting the task they were presented to do was.

Hsin-Kai et al (2022) states how “AR superimposing virtual objects or information onto physical objects or environments enables visualization of invisible concepts or events” this benefit of AR could be better visualised in this application by adding electrical signals. The concept of using AR to superimpose virtual information to the user was also proved to be very useful for the user to understand what they needed to do, because between the two tests one of the biggest changes was adding in additional text to help guide the student to creating a circuit, and from this 92.4% of students were able to get the circuit to work.

This project also agrees with some of what Radu (2014) states, in that AR provides opportunities for teaching 3D spatial and kinaesthetic content and can increase student motivation, although this project is unable to agree with Radu (2014) conclusion that AR can increase the long-term memory retention of taught information as this project did not test for long-term memory. Though after the answers from the quiz asking if users thought they could re-make the circuit most responded that they did not think they would be able to.

The paper by Di Serio et al. (2013) which uses the IMMS to assess if AR can improve motivation come to the same conclusion that using AR can help to improve the motivation in students.

During the testing some students missed out on some of the important information, most students who used the application in either of the tests did not end up using the feature to play the animation of the different components. In the second test it was also seen that some of the students did not read the additional information whilst they used the application on the first go through of the different stages. When the circuit did not work, and they were prompted to use the application to try and fix any of the issues that they had, the students then read the tutorial information which helped them get a working circuit. This result is like the conclusion Radu (2014) made where a problem with using AR is attention tunnelling, where students would focus so much on the AR element of the application that they would ignore some of the other features and not use them unless prompted to.

The system used by Reyes-Aviles et al. (2018) would have been very useful to use in this project. They used a marker-less system to track the location of the breadboard. This would have solved one of the minor problems that occurred during the testing which was that the virtual breadboard would move a lot and could float around the screen if the user was not directly looking at the QR code.

### Limitations of evaluation

The biggest limitation of this evaluation is that the sample size for both tests were small consisting of 7 and 13 people. This number of participants is not enough to ensure the reliability of the results gained from the test. Another limitation is that the participants who took part in the first test also took part in the second test. Due to the structure of the tests being the same as each other, apart from the updated content to the application, it gives the participants who took part in the first test a slight advantage in what knowledge is known before participating.

# Conclusions

The project has been focused on creating an AR application to help students build an electrical circuit. This has been done by following the main aims of the project:

* Investigate the current uses of AR in education.
* Investigate the different components in an electrical circuit for the application.
* Design and create an AR application for electrical circuits.
* Evaluate the effectiveness of the application to make improvements to it.
* Test the application with the target audience of university students.

The current use of AR in education was found to be limited. Some projects that have created AR applications to help teach topics in an educational environment have been highlighted, but the main conclusion is AR in education is still in its early stages of development.

This project has shown how an AR application has been created which is able to help students learn how to use electrical components on a breadboard. The components used are button, resistor, LED, and wires.

By using the agile methodology, it allowed for the project to be tested multiple times, this gave time for the effectiveness of the application to be evaluated so that appropriate changes could be made to help improve the application.

The project has been tested on university students which gave vital feedback and information on how effective the application is with the target audience.

Overall, the system can be called a success. It was found that by using AR to help teach university students, it can improve the motivation and productivity of the students. It was also highlighted how students can get tunnel vision and focus on the AR elements so more research needs to be done to help reduce the amount of tunnel visioning.

# Recommendations for future work

This project can have some improvements made to it that can help to further test how AR can be used in an educational environment such as:

* The application can have more circuits for students to test out on it. This will allow for a better understanding on what type of circuits are best suited being taught using AR.
* The program can be updated to using a marker-less tracking system to locate where the breadboard is to create a more stable environment.
* Research into how AR can create tunnel vision is also a big topic that will require further research into to work out way to minimise the amount of tunnel vision students get when using the app.

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# Appendices

## Gantt Chart

Timeline

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