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RESEARCH PAPER

Improving instructional technology using augmented and virtual reality

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Abstract

This study examined the effects of virtual and augmented reality (ar/vr) on educational technologies. Making a mobile AR/VR application that enables students to view and interact with computer hardware in a virtual lab environment is the project's main objective. One of the most popular object-oriented programming languages (OOP) for making mobile applications, especially for the Android and iOS platforms, is C#, which is used in the development of mobile AR/VR applications. The application created in C# will work with both iOS and Android Smartphones. This approach is built on a synthesis of several approaches and prior knowledge of both traditional and virtual reality programming. Because of the interactive environment known as the AR environment, hardware concepts can be more clearly conveyed with the help of three-dimensional graphics. The results of the study have implications for the application of AR/VR technology in education and highlight the need to provide money for its development and integration into curricula. The study's conclusions demonstrate how integrating AR and VR technology into the classroom can provide students with an immersive and interesting learning environment that will aid in their increased retention of the subject matter.

Keywords: Augmented Reality, Virtual reality, 3D model, Mixed reality, e-learning.

Introduction

Promoting online training in response to epidemics should spark a new training frenzy in the modern day. One type of education that is growing in popularity and like is e-learning. Although there are many advantages to online learning, there are also many areas in which it is inadequate (Cooperstock, 2001). A great deal of hands-on instruction is required for the disciplines in fields such as athletics, dance, and visual arts. How and what technological solutions could be developed to enable simultaneous learning of theory and practice is the question. Numerous applications will have positive effects and reinforce learning to improve practical teachings and learner interaction with teachers and other learners in a multi-dimensional space created by computers (Lam et al., 2021).

It has become more and more important to provide augmented reality and virtual reality explanations of computer hardware components to encourage student engagement, improved understanding, and memory retention, facilitate remote learning, and promote these technologies (Oluwaranti et al.,2015). Augmented reality (AR) technology combines digital information with the real environment. Other technical methods include sensing, 3D modeling, real-time tracking and registration, intelligent interaction, and multimedia. The idea behind this is to imitate the real world before adding computer-generated virtual information to it, such as text, images, 3D models, music, and videos. Because of how well the two sorts of knowledge complement one another, the real world is enhanced. For a better understanding of this research paper, understanding and knowledge of some terms will be very important. Augmented reality is defined as an interactive experience of an enhanced version of the real physical world. It is a system that incorporates real and virtual world interaction in real-time and 3D Models of real and virtual objects. Virtual Reality is a simulated artificial environment that is designed and implemented with software and presented to the user such that the user takes it as his/her real world. The method's outputs lead to the creation of a virtual environment scenario description, lists of assets and state machines (Polcar et al., 2006). Mixed reality refers to environments or circumstances where both virtual reality and augmented reality are utilized to enhance user interaction and experience. Industry standards refer to the use of computers to enhance instruction and comprehension as "e-learning." As a result of the recent COVID-19 Outbreak, our understanding of e-learning has recently been centered on virtual learning tools and software. The primary goal of this project is to create a Smartphone application that combines augmented and virtual reality and to demonstrate how AR/VR can be used to teach computer hardware. The study by AlNajdi, et al. (2020) has also shown that augmented reality (AR) can be helpful to users who are building computer hardware. It bestows a mystical perspective upon the material object. As a result, assembling things becomes simpler. Due to the absence of most computer hardware concepts in Nigerian Universities and other Universities in African, it is only important that a solution is created to help explain and showcase these concepts. This research helps to find loopholes and improve the existing Augmented Reality and Virtual Reality Solutions. Software engineers and Metaverse Engineers may adopt the research work looking to improve and create improved AR/VR tools. This product will be immediately adoptable by Teachers/Lecturers and Learners and will contribute to the research of Mixed Reality (Augmented and Virtual Reality) as it provides a more interactive method of teaching and learning.

Review of Related Works

VCRs, document cameras, and computer projections are just a few of the multimedia presentation technologies available to instructors in electronic classrooms. Transparencies, computer simulations, and animations can all be displayed using these technologies (Lam et al., 2021). Nevertheless, many teachers still find the technology time-consuming and difficult to use, despite its user-friendly design. Additionally, technology frequently takes the teacher's focus away from the primary instructional goal, which results in underutilization. (Lam et al., 2021). Virtual and augmented realities are considered powerful teaching tools because they theoretically offer experiential learning without requiring the learner to move when real-world scenarios are accessible (Fabri et a., 2008). Technology needs to have extremely challenging features and performances in order to obtain good experience learning. In the field of e-learning, where it is sought to provide each student rich, customized education, these expectations are becoming more and more significant (Fabri et al., 2008). An Android-based augmented reality tool has been developed using the Tesseract API to store and provide enhanced information about participants in various sporting events. The marker-based technique is used by the augmented reality system to register virtual content (Oluwaranti et al., 2015). Virtual reality, or VR, substitutes a simulated experience (virtual world) for the actual world. With augmented reality or AR, one can simultaneously experience the real world and a virtual one (Bacca et al., 2014).

A mobile learning application was developed using augmented reality (AR) to enhance students' educational experiences (Chen et al., 2019). The marker-based technique of the AR system developed by Chen et al., 2019) uses the built-in camera of the mobile device to track visuals and record virtual material. Scannable images were recognized using the Vuforia Cloud Target Recognition System (VCTRS). Object-oriented principles were used to model the application, which was developed using Java programming on the Android platform. The system's average scores for usability, learnability, and efficacy were 6.25, 7.75, and 5.75, respectively, according to the evaluation's conclusions. The study found that AR provides students with a more effective and satisfying learning environment.

Fernandez (2017) offers an original method for creating virtual reality environments. It leverages game development IDEs as the platform and builds on previous experience with both traditional and virtual reality programming, along with a variety of other methodologies. The approach was first designed to create a virtual therapeutic game, but it has since been shown to be successful in a number of other applications. The procedure yields a state machine and asset list in the end, as well as a virtual environments scenario, a list of required objects and their states, and an action list for changing the states. In assessing the educational uses of augmented reality and virtual reality,

AlGerafi et al. (2023) place particular emphasis on how these technologies affect student motivation, learning results, engagement, and general learning experiences. The study examines how AR and VR can enhance student learning, retention of information, and acquisition of skills by methodically examining the body of research from a variety of educational fields. In conclusion, the research shows how AR and VR have a significant impact on education by shedding light on the benefits, limitations, and challenges of carefully deciding how to use these technologies to create engaging, memorable learning experiences that will foster the growth of a new generation of technologically savvy, knowledge-driven students.

An overview of augmented reality technology and its uses is given by Pirker et al., (2020) in the paper titled An Overview of Augmented Reality. It begins by going over augmented reality research and development on a national and international level. The paper then discusses the key technological elements, development aids, and real-world uses of AR in diverse industries. The study also makes predictions about how augmented reality will develop in the future, including the idea of an AR cloud.

The expanding use of virtual and augmented reality technologies in education is explored in Huerta et al., (2020). The advantages of adopting experiential learning methods for knowledge acquisition are highlighted by the authors along with the difficulties in integrating these technologies to improve students' learning outcomes. The study takes into account all parties involved in the use of technology in education, including teachers, students, institutions, and producers. The authors of this study stated that virtual and augmented reality technologies have not been widely adopted and that teachers need to be given training in how to use them in useful educational contexts. It is suggested that a six-step technique, consisting of teacher training, conceptual prototype development, teamwork, production of the experience, and deployment in a subject with students, be used to help integrate these technologies into normal education. The consideration of business potential in both traditional and online education serves as the essay's conclusion.

According to Uddin et al. (2019), the COVID-19 pandemic has had an impact on education and compelled institutions to implement online learning methodologies. There isn't much interaction, which causes problems for the conventional teaching style. It is hypothesized that the use of virtual reality technology in online education will improve the quality of interaction between students and teachers since it immerses them in a virtual world and eliminates distractions. The study emphasizes the shortcomings of the current online learning paradigm and suggests enhancing teacher-student engagement using virtual reality (VR) technology. Synthesis, statistics, analysis, and comparison are all incorporated in the methodology.

In their study, Salako et al. (2021) investigated the use of virtual reality (VR) technology in computer science education. The authors do a thorough analysis of the possibilities and uses of virtual reality (VR) for computer science education. The study focuses on finding factors that pertain to using fully immersive VR for computer science education, such as learning objectives, technology used, interaction qualities, challenges, and advantages. The purpose of the paper is to provide an official assessment of the literature on the use of virtual reality (VR) in computer science education. The authors want to show how virtual reality (VR) can open up new avenues for interactive learning and work, especially in the STEM professions.

Yuen et al., (2011) look into how technical drawing principles are taught in higher education settings using augmented and virtual reality (AR/VR) technologies. This paper aims to examine the impact of AR/VR-based methods and tools on the teaching and learning experience due to worries regarding the fall in technical drawing standards. These tools were created using the findings of an earlier international study on how technical drawing education is perceived, evaluated, and anticipated.

Aldalalah et al., (2019) recommended AR & VR learning programs as a novel way to teach children the alphabet and other educational material. Children can have an immersive experience thanks to the usage of augmented reality and virtual reality technologies, which makes learning more participatory and fun. Children can use the app to view a 3D visual depiction of an object while holding the phone camera over a page in a book and seeing the name of the alphabet and a word linked with it. Children can roam about a 3D world and gather alphabets while listening to the names of the letters as they do on the VR app. The app is designed based on the results of a survey, and it takes advantage of children's love for using smartphones to improve their learning experience.

The outcomes of utilizing inexpensive interactive marker Augmented Reality (AR) technology in computer graphics are shown in Gutierrez et al., (2008). Through a model study, the authors have investigated how augmented reality technology might be used to improve teaching and learning. Based on the principles of human-computer interaction, two learning scenarios have been created to give students a dynamic and interesting method to learn crucial ideas. The findings demonstrate that augmented reality (AR) technology is regarded as a promising and efficient tool for enhancing theoretical concept knowledge, encouraging original thought, and creating more realistic 3D models and settings. The opinions of the students were gathered, and the results suggest that AR technology is seen as a valuable tool for enhancing the learning experience in computer graphics.

An overview of Augmented Reality (AR) technology and its possible effects on education and learning is given in Pirker et al., (2020). It looks at the most recent advancements in augmented reality, including its growing use across a range of industries. The report also examines how augmented reality affects society and assesses its prospective effects on education, such as how it could promote ubiquitous learning by giving quick access to cite specific data. The study's forecast for the future of augmented reality on US college campuses is its conclusion.

The students who got teaching via augmented reality technology had much superior academic achievements and visual thinking skills than those who received instruction through simulation, according to the authors in Azuma (1997).

The authors in Donnelly et al., (2021), suggested particular steps for minimizing learning losses and getting ready for the reopening of the school. The opportunity to create and implement structural changes to strengthen education systems and, as a result, raise students' academic performance is also covered in the article.

From its inception through to its primary applications and key facts, Arena et al., (2022). Provides an overview of augmented reality. The study went into great length about the hardware and software components utilized in AR systems, as well as about the design constraints, drawbacks, and potential future applications of this remarkable technological advancement.

The researchers in Elsayed & Al-Najrani (2021) used a quasi-experimental approach with an experimental group, a control group and pre-test and post-tests for both groups in order to determine the efficacy of augmented reality technology in enhancing mathematical visual thinking. The Academic Motivation Scale and the Visual Thinking Test were used as research methods on a sample of 76 students chosen at random for the study. The outcomes has been suggested that using augmented reality technology can help pupils develop their visual thinking abilities and improve their arithmetic learning outcomes.

Researchers in Salako et al., (2020): suggested using Responsive Templating, an end-user programming paradigm, to create virtual online innovation laboratories and control the activities that take place there. According to the authors, this will go a long way in assisting facilitators in a university who have little to no experience with developing virtual worlds and programming to organize virtual online discussion groups for their student teams.

Tang et al., (2020) evaluated the basic workflow of the VR software development process as well as the most modern 3D modeling and texture painting methods utilized in VR. The authors outline some of the most important computer graphics and 3D modeling methods that can be used in VR to speed up interaction. One of the primary strategies mentioned was the use of mesh editing modifiers and smoothing techniques.

The goal of this study is to create a mobile-based augmented and virtual reality application to support computer hardware education in educational institutions. The previous few years have seen a huge amount of work done on AR/VR, but from the reviewed literature, not much has been done in the way of creating a mobile AR/VR application for teaching computer hardware, which is why this study is necessary. The study looks at how computer-generated audio, virtual worlds, screenplays, and 3D models can be created using AR/VR technologies.

Methodology adopted for the mobile-based AR/VR application

The methodology of the mobile-based AR/VR application implementation refers to the specific techniques and methods used to develop and deploy the application. Here are the steps involved in the methodology of the mobile-based AR/VR implementation that allows students to view hardware devices and listen to computer-generated audio content.

Step 1: Defining Scope and Goals. Firstly, the scope and goals were defined:

- The project aims to develop a mobile-based AR/VR application that allows students to view and interact with computer hardware devices in a virtual lab environment.
- The application will be available on Android and iOS devices.
- The application will use marker-based tracking to accurately position and orient the virtual hardware devices in the user's view.
- The application will include computer-generated audio content to enhance the learning experience that explains the components of the hardware devices being viewed.

Step 2: Choosing Development Platform: The next step was to decide on which development platform to use. Unity 3D was chosen as the development platform as it provides the tools and libraries needed to create (design and integrate) the virtual environment and interact with the hardware on Android devices. The time and money required to develop AR/VR applications can be significantly decreased by using a gaming engine like Unity or Unreal Engine. Game engines offer a variety of tools and libraries that make it simple for developers to build virtual worlds and communicate with hardware, making them ideal for AR/VR development.

Step 3: Creating a virtual environment. The success of AR/VR applications can be considerably impacted by the virtual environment's architecture, according to research. The user's engagement and learning results can be affected by a variety of factors, including aesthetics, interaction, and overall user experience.

The virtual environment:

This was designed to represent a homely environment. The initial plan was to design a computer lab but this proved difficult as some key elements were difficult to come by and design (that is inspirations)

The virtual environment also includes 3D models of a desktop computer setup. That is, monitor system unity, mouse, and keyboard as well as computer-generated audio information about them.

Step 4: Tracking and Localization: Here, the location of an object in space (Localization) and its position over time (Tracking) were both calculated. According to research, marker-based tracking is an effective and dependable method for AR/VR applications, especially when combined with other tracking techniques. Numerous AR/VR applications require high-precision tracking and orientation data, which marker-based tracking may deliver.

For the tracking and localization system, marker-based tracking was used to estimate the device's pose relative to the markers placed in the real world. The markers are placed at the physical hardware devices and will have known positions and orientations.

Step 5: Testing and Debugging: This phase in the development of the mobile-based AR/VR application was crucial. In this testing step, the program was assessed to see if it fulfilled the project's objectives and specifications, and in the debugging phase, no problems or flaws were found that needed to be fixed. According to research, extensive testing and debugging are essential to the success and caliber of AR/VR apps. To provide a positive user experience, testing the application across a variety of platforms and gathering user input can assist uncover and correct problems or defects in the program.

The following were carried out to properly test and debug the mobile-based AR/VR application.

Test on a range of devices: It is important to test the mobile-based AR/VR application on a range of devices to ensure that it functions correctly and performs well on different hardware configurations. The implementation was tested on different device models and screen sizes. Some of these device models include: the Redmi Note 10Pro and Samsung S22 Ultra

Test the tracking and localization: The tracking and localization system is a critical component of any AR/VR application, as it enables the application to accurately position and orient the virtual environment in the user's view. It was important to thoroughly test the tracking and localization system to ensure that it functioned correctly and performed well in different environments.

Test for performance and stability: The performance and stability of the mobile-based AR/VR application is critical for a good user experience. It was important to test the application for performance and stability to ensure that it ran smoothly and did not crash or freeze.

Collect user feedback: User feedback is an important source of information for identifying and fixing issues or defects in the mobile-based AR/VR application. It was important to collect feedback from some users during the testing and debugging phase to identify any issues or areas for improvement.

Design of the AR/VR system

A. AR/VR system architecture

The architecture of AR/VR is made up of the mobile device, operating system, AR/VR framework application assets and application logic. The application assets consist of 3D models, 2D images and virtual environments. These assets are to be bundled into the application to better enhance the interactivity of the application.

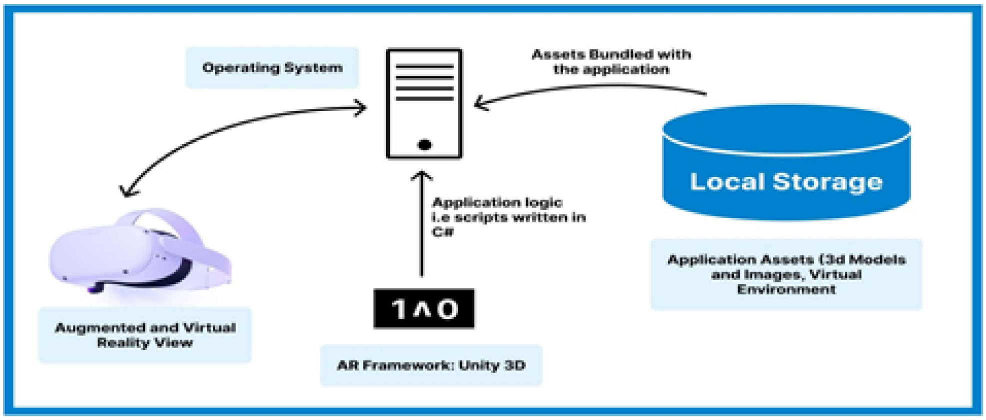

Figure 1: System architecture for mobile-based AR/VR application

Mobile device

The mobile device, such as a smartphone or tablet, serves as the primary platform for the AR/VR application. It is responsible for displaying the AR/VR content to the user and capturing input from the user. Operating system: The mobile device's operating system (for example iOS, Android) provides the framework for the AR/VR application to run on. It handles tasks such as managing system resources, displaying the user interface, and handling input and output. Figure 1 depicts the system architecture and design for the proposed AR/VR mobile-based application.

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AR/VR framework

The AR/VR framework is the software library that provides the necessary tools and APIs for the AR/VR application to interact with the mobile device's hardware and operating system. This includes functions for displaying 3D graphics, tracking the device's position and orientation, and handling user input. For this research work, Unity is the framework used. Unity is a cross-platform game engine that supports the development of AR/VR applications. It provides a range of tools for creating 3D graphics, handling user input, and integrating with external APIs.

Application logic

The code that specifies the particular functionality of the AR/VR application is called the application logic. This covers processing user inputs, presenting 3D models, and playing music or video. In order to handle user input in Unity 3D for the application logic functionality, a script was written. This script creates an event listener that recognizes user input from a variety of input sources, including keyboard, mouse, and screen touch, and reacts to the input by, for example, initiating a particular action or behavior.

Data storage

The AR/VR application will need to store data locally on the mobile device, such as user preferences or application data, or it may need to access data stored on external servers.

B. System algorithm

In developing the mobile based Ar/Vr application, the following algorithms were used.

Algorithm 1: for audio processing

To Load the audio data into memory
// The first step is to load the audio data from a file or stream into memory. This may involve using a library or API to read the audio data from a file or network connection.
Process the audio data
//The next step is to process the audio data according to the specific requirements of the application. This may involve applying filters, effects, or transformations to the audio data, such as spatialization, equalization, or pitch shifting.
Output the audio data
//The final step is to output the processed audio data to the user's device. This may involve using a library or API to play the audio data through the device's speakers or headphones

A C# script was created to import an audio clip from a file into Unity 3D using the AudioClip and AudioSource components in order to implement algorithm 1. The LoadAudioData() function can be used to load audio data from a file.

Algorithm 2: for 3D rendering

Load the 3D model data into memory
//The first step is to load the 3D model data from a file or stream into memory. This may involve using a library or API to parse the model data and create a representation of the model in memory.
Transform the 3D model data
//The next step is to transform the 3D model data according to the desired position, orientation, and scale of the model in the virtual environment. This may involve applying transformations such as translation, rotation, and scaling to the model data.
Rasterize the 3D model
//Thenextstepistorasterizethe3Dmodel,whichinvolvesconvertingthe3Dmodeldatainto a 2D image that can be displayed on the user's device. This may involve algorithms such as triangle rendering, z-buffering, and shading to generate a high-quality image.
Display the image
//The final step is to display the rasterized image on the user's device. This may involve using a library or API to draw the image to the screen or render it to a texture.

Using the transformation occurring at "instance transform., position" and "instance transform. rotation," a new object is formed and its position and rotation are set in the C# script generated for this algorithm. A public variable of type "Game Object" named "model" is displayed by the script.

To store a reference to the 3D model asset that will be displayed, this public variable needs to be created at the start of the program.

Algorithm 3: For Tracking and Localization

Initialize the tracking system
//The first step is to initialize the tracking system by setting up the sensors and other hardware components that will be used to track the device's pose. This may involve calibrating the sensors, setting up the device's camera, or configuring other hardware components.
Collect sensor data
//The next step is to collect data from the sensors, such as the device's camera, accelerometer, and gyroscope. This data will be used to estimate the device's pose.
Estimate the device's pose
//The next step is to use the collected sensor data to estimate the device's pose. This may involve using algorithms such as visual-based tracking, inertial-based tracking, or marker-based tracking, depending on the specific requirements and constraints of the application.
Update the virtual environment
//The final step is to update the virtual environment based on the estimated device pose. This may involve updating the positions and orientations of 3D models, displaying virtual overlays in the real world, or updating the user's view of the virtual environment

The c# code written for this algorithm is given below. Figure 2 shows the initialization of the tracking system, the data collection sensor, the device's pose estimator and the virtual environment update.

```
// Initialize the tracking system
InitializeTracking();

// Collect sensor data
Vector3 acceleration = Input.acceleration;
Quaternion orientation = Input.gyro.attitude;

// Estimate the device's pose
Vector3 position = EstimatePosition(acceleration, orientation);
Quaternion rotation = EstimateRotation(acceleration, orientation);

// Update the virtual environment
UpdateVirtualEnvironment(position, rotation);
```

Figure 2: Script written in C# to display a Model in Unity 3D

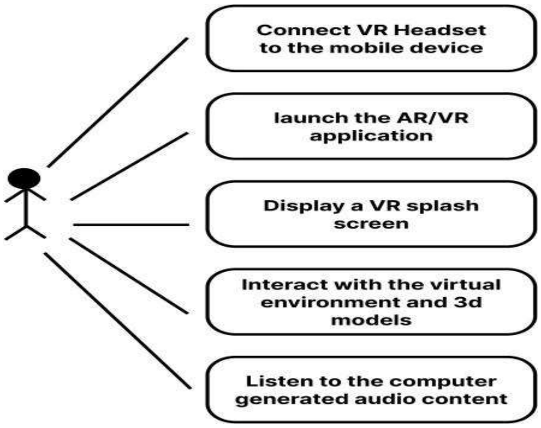

Figure 3: Use Case diagram for Mobile-Based AR/VR Application

Figure 3 depicts the Use case diagram for the mobile-based AR/VR application. A user wishes to learn more about computer hardware using a mobile application that uses augmented reality (AR) and virtual reality (VR). They download a mobile AR/VR app that enables them to gain knowledge through engaging activities in a virtual setting. The application allows the user to explore new ideas, interact (see) with virtual characters and objects, and listen to audio that has been produced by computers.

Preconditions:

The student has a smartphone or other mobile device that is compatible with the AR/VR application.
The student has downloaded and installed the AR/VR application from an app store.
The student has a mobile VR headset.

Steps:

The student connects the VR headset to their mobile device which supports the AR/VR application.

The student launches the AR/VR application on their mobile device.
The application displays AR/ VR splash screen view.
The student interacts with the virtual environment (viewing). The student listens to computer-generated audio content.

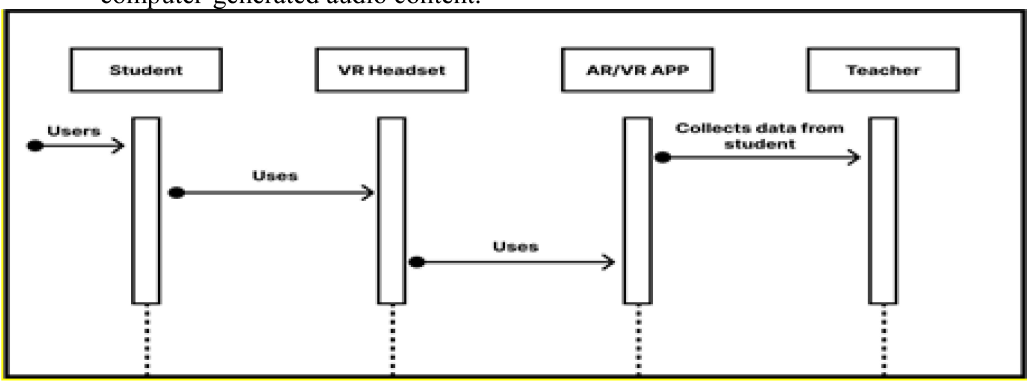

Figure 4: Sequence Diagram for Mobile-Based AR/VR Application

The student utilizing the VR headgear and the AR/VR mobile app, which are the major instruments to improve the learning experience, is at the center of the diagram in Figure 3. The AR/VR smartphone app offers additional information and visual aids, while the VR headgear offers an immersive and participatory view of the human body. The teacher, who is in charge of the curriculum, scheduling, and evaluation of the pupils, is in charge of both of these resources. The learner receives instructions from the VR headset to put on the headgear and begin the immersive experience. The interactive learning experience is then launched by the mobile AR/VR app. According to the teacher's instructions, the student interacts with both tools. The instructor monitors the progress of the students by providing comments and assessments while they interact with the AR/VR mobile app and VR gear. Also, the teacher sends a message to the data collection component to obtain the student's performance data, which includes the grade, time spent, and feedback. This implies that the duration spent using the immersive application would likewise be recorded. The gathered information is then kept in a database for future study. The information gathered comprises the student's performance, the amount of time spent on each educational task, and the student's feedback. This information can be utilized to assess the impact of AR and VR on student learning outcomes and to pinpoint areas for development. The relationships between the major parts of your project, "Enhancing Educational Technology through AR/VR," are summarized in this sequence diagram as depicted in Figure 5. The interactional flow between the students, the VR headset, the AR software, the science teacher, and the data gathering is displayed. The system's data flow is also shown in the diagram, along with the main duties of each component. It offers a clear visual picture of the interactions and connections between the many system components, making it simpler to comprehend how the system functions as a whole.

Implementation

This section describes how the design from the previous chapter was used as a foundation to implement a mobile Ar/Vr application. The augmented and virtual view/experience's individual components are explained in detail in the subsections that follow.

A.3D Model

The usage of 3D models in AR/VR applications gives the subject matter a highly visual and interactive portrayal. As a result, students were better able to comprehend the physical makeup and individual parts of the hardware, which was helpful when teaching computer hardware components. To show how the parts function and relate to one another, the models were animated.

A. ***Virtual environments***

The immersive experience offered by the virtual environment gives the students the impression that they are actually in the realm of computer technology. The virtual environments are meant to replicate real-world scenarios or to create an abstract setting that is especially appropriate for studying computer technology. Figure 5 from Unity Hub shows a Virtual Reality View of a Virtual Environment.

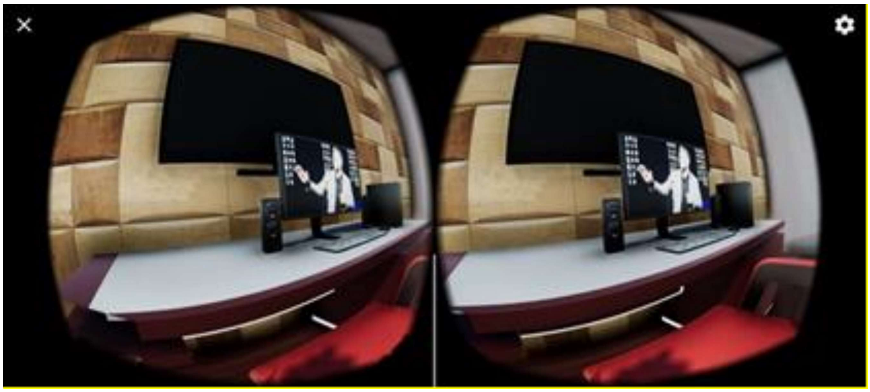

Figure 5: Virtual Reality View of Virtual Environment

A. ***Computer-generated audio content***

Additional information, justifications, and directions were given via audio content. By including digital voices, sound effects, and background music, it was used to make the experience more engaging and interactive.

B. ***Scripts***

The set of instructions known as scripts, which are written in a programming language, regulate how the mobile application and other parts behave. The reason C# was chosen was because it is a multi-paradigm programming language that can be utilized for many different purposes, including creating mobile applications. Figure 6 illustrates how C# scripts were utilized to regulate the behavior of computer-generated audio content in the context of this mobile AR/VR application. Controlling these elements' motion, animation, and interactions in the AR/VR environment falls under this category.

Figure 6: Screenshot of C# Scripts Written for the Audio Controller

Results and evaluation

The set of instructions known as a script is written in a programming language. The following tests are used to assess the implementation's effectiveness: test on a variety of gadgets, Test the localization and tracking. Perform stability tests and obtain user opinions.

A. **Test on a range of devices**

The following procedures were followed in order to test the AR/VR mobile app on various gadgets:

1. Identify the targeted devices: The first step was to determine the platforms on which the AR/VR software will be tested, taking into account the various operating systems, screen sizes, and resolutions. The mobile app in this case was created exclusively for Android operating systems.
2. Establishing the test environment: After installing the mobile application on the devices, the next step was to establish the test environment.
3. Application test conducted on several devices that were intended for the test. This was physically observed.
4. Data analysis: Examine the information gathered during testing to find any problems or flaws that need to be rectified.

Table 1. Explanation of the test result

Mobile Device	Issues	Result
Redmi Note 10 Pro	No issues found	Pass
Samsung Galaxy A02	No issue found	Pass

A. *Comment:* It's crucial to test the AR/VR mobile software across a variety of platforms to guarantee its compatibility, functionality, and user experience. The testing process's outcomes, which are presented in Table 1, assisted in determining the app's overall quality and preparedness for release.

B. Test Tracking and Localization

For testing the tracking and localization, a mobile device and virtual reality headset were the two primary requirements. This made it possible to move around in 360 degrees while viewing the virtual surroundings. The test verified the program's abilities to identify and orient the user within the virtual environment, as well as its capability to react to the user's change in direction while donning the VR headset.

C. Test for performance and stability

There are several recommended techniques for stability and performance testing. A few types of testing include volume, stress, load, and endurance tests. For this investigation, tests of stress and endurance were performed. The application was continuously run for a significant amount of time in order to evaluate the application's performance degradation over time and ascertain its performance and stability under these conditions.

Table 2: Testing for performance degradation

Observation	Reason	Solution
The application takes too long a time to load. The load time was discovered to be between 32 and 36 seconds	Large files and outdated hardware/incompatible mobile device	• Reduction of the size of the files (audio contents, images and models). • Hardware upgrade and/or use of compatible mobile device

Comment: It is crucial to test for performance degradation to verify that the applications' performance won't vary over time and, if it does, to identify the causes and potential solutions. The test results displayed in Table 2 assisted in illuminating the observation, justification, and solution.

User feedback collection

The feedbacks collected were categorized into different categories. They are:

Positive Feedback: The application has an interesting interface

Negative Feedback: The application takes time to load

Suggestion Feedback: The application could do with more computer hardware and audio computer audio content to help explain the newly added hardware. Also, if there are no added hardware then more audio computer-generated content can be added.

Technical Feedback: The application takes time to load.

Feature Request Feedback: Better interaction would make the application more live that is, allowing the user to be able to move around (that is, change position) or even interact with the 3D models.

User1Feedback: I could not interact with the application as it was static. I could move around.

Visit the link below to see a recording of this test being carried out. *https://drive.google.com/file/d/1bGz6atAxDrknJAjZmYvcHXkvc4qcXQXP/view?usp=share_link*

User2 Feedback: I was able to see a home computer setup. Also, I heard a robotic sound explain what a computer is.

Visit the link below to see a recording of this test being carried out.

https://drive.google.com/file/d/14un2HexwYM4vLCN9GXy_nntK3naAgoOh/view?usp=share_link

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