

An Augmented Reality Based Model for Secondary School Students with Improved User Experience

Nasir Mehmood*

Department of Computer Science, University of Sialkot, Sialkot, Pakistan.

*Corresponding Author

Nasir Mehmood

Department of Computer
Science, University of
Sialkot, Sialkot, Pakistan.

Article History

Received: 11.07.2024

Accepted: 19.07.2024

Published: 04.08.2024

Abstract: This study aims to formal inquiry to discover and examine the facts of the usage of Augmented Reality (AR) in learning science subjects. The research presented an overview of AR Technology in education using the Constructivist Learning Theory (CLT) model along with educational strategies and also provided an analysis of the results of using the AR-based model. The study was conducted students of four different schools of Sialkot, Pakistan in the session of 2022-2023. The study was conducted on 160 students aged 11 to 16 years from four different schools in Sialkot, Pakistan in the session of 2022-23. Students were divided into two groups of equal number of students: one control group and other one experimental group. There were 4 experimental and 4 control groups in total. This methodology has evolved in students learning through traditional method and AR-based model. Methodology used both qualitative and quantitative (mixed) approaches and data collected through pre-test & post-test. As a data collection tools were used: "Achievement Test with Open-Ended & Close-Ended Questions" for result collection, "Attitude Scale Test towards AR Technology" for student's mentality level checking and "Semi-Structured Interview Form" for opinions. An attitude scale test was initially conducted, followed by a comparative study using both traditional classroom methods and an AR based model. This research explores the impact of these methods on attitudes, with a focus on aligning with constructivist learning principles. A sample of the study was randomly selected 80 students out of 160 for the control group and the rest for the experimental group. After obtaining the results using the traditional methods and AR-based models, the researcher applied p-test and t-test, which showed that the learning outcomes of the students have been increased by using AR-based model. The researcher has applied HCI Heuristic Evaluation (HE) to the proposed AR model and also collected the results of semi-structured interviews, attitude scale test towards AR technology which showed that the use of AR in education has enhanced the user experience and students learning outcomes.

Keywords: AR, 7E Constructivist Learning Theory Model, Heuristic Evaluation, Education, Students Learning Outcomes (SLO's).

Cite this article:

Mehmood, N., (2024). An Augmented Reality Based Model for Secondary School Students with Improved User Experience. *ISAR Journal of Science and Technology*, 2(8), 15-39.

1. Introduction

Augmented Reality (AR) has found extensive application across various fields due to its user-friendly nature and adaptability for everyday use and education. This technology is rapidly gaining global traction, particularly in the education sector, where its integration promises enhanced learning experiences for students, making education engaging and enjoyable. AR serves as a visual medium, offering immersive virtual experiences that allow users not only to see but also hear and feel simulated realities, blurring the lines between virtual and actual environments [1]. AR used in real world environment where show in real using different sensors objects [2]. AR is an interactive experience in a real-world

environment in which real-world objects are imagined and projected into our vision. There are two main types of AR: Marker-Based AR and Marker-Less AR [3]. **Marker based AR** is created using image recognition to identify objects already programmed into your AR device or application. When presenting an object in front of the AR camera, the AR app determines the position and compares the object to images already stored in the database and after matching that image is placed in the right place. As shown in Fig.1, if researcher puts the mobile camera in front of the page image, AR device or app using image recognition that already programmed in AR device image objects, match and identified with that image and create image in real.



Fig 1: Marker-Based AR View

Marker less AR is more complex because in this type recognition and detection feature are used. The device uses the color, pattern and similar feature of the object and detects the image and displays the results [3]. As shown in the Fig 2, if researcher bring the mobile camera in front object, AR device or app using recognition algorithm to determine colors of that place, patterns and similar features of that object you focused with the help of time, GPS sensors, accelerometer and compass, researcher saw the object information.



Fig 2: Marker-Less AR View

There are three significant components of AR: **1. Input and Output devices:** Head Mounted Device (HMD), smartphone, monitor and smart glasses used for I/O hardware devices in AR. With the help of camera, gyroscope, sensors, and location to identify the objects or place and get the information of that object and share the information on AR app or web server software for processing. After reading data through app or web server, augmented content sends back to the device for output view. **2. Software and apps:** are the intermediaries between AR devices and servers. There are many apps and games like Assembler education, Photo math, google lens, Instagram, Poke mongo Ingress etc. which uses AR technology. Software's like AR Kit, AR Core, Vuforia, etc. help to create virtual objects. **3. Servers:** used as a database storage room that store all the virtual objects that are created through apps, webserver or cloud server [4].

Mobile Augmented Reality (MAR) is a type of mobile application, sometimes built-in and sometimes user defined. MAR is easily to interact with each other using mobile phones app and displayed virtual reality [5]. MAR Applications are effective for preschool children to deal with problems in the monitoring and use of markers in AR applications. AR applications in school education have proven to have significant benefits. School children are said to have potential groups to explore future uses of AR. [6]. Many AR applications have been developed for a wide variety of learning domains, such as STEM [7]. AR is used for 3D video graphic and digital pictures in education for better learning [8].

Pedagogical strategy is an abstract teaching method, style, behaviorism in education. AR systems can help to expand the possibilities and improve learning usability and processes of technology in education [9]. Using AR technologies teachers can enhance classroom experiences, teaching new skills, enhance student thinking for new ideas and get students expectations of new

academic interests and passion. AR has a significant impact on the learning environment, like, student engagement and interest, learning environment, content understanding, collaboration, memory, sensory development and Cost effectiveness.

AR is a web-based technological development that can align with the CLT Model. CLT models include the 3E, 4E, 5E, and 7E [10]. Eisenkraft [11] considered the 5E model inadequate, so he aimed to address its shortcomings by creating a new model. He introduced the 7E model, which is based on higher training steps. Teachers need to invest a bit more effort in understanding the 7E model during the lesson planning and preparation phase because the steps are longer and slightly more challenging than in the earlier models.

This paper is about augmented reality and its effectiveness in education. The paper has discussed integrating an Augmented Reality-based model into the CLT model to improve the user experience and help students become more involved in learning using local-level language augmented reality apps. An interactive learning environment provides opportunities to implement hands-on learning approaches that can increase engagement, enhance the learning experience, and encourage students to learn and practice new skills using the 7E learning model. The teacher helps generate a quality of ideas in students' minds for the best use of AR technology in study, provides opportunities to share ideas and feelings, and explores images to assess the advantages of the CLT Model to facilitate teaching and learning.

Design an app for international and local-level users to convert 2D book pictures to 3D using Augmented Reality applications. AR technology can help improve the user experience, students' engagement, and the learning environment within the 7E Learning Model. Study through MAR apps into CLT model to evaluate

results using Pre-test & Post-test technique and collect data through semi-structured interviews and questionnaire forms.

The research is based on Augmented Reality (AR) and its apps using the CLT model in education. The AR apps in education are chosen based on the lack of technology use in education for practical work and have not been discussed before in the literature. The accuracy of the result findings using MAR apps in the 7E learning model is higher than the previous work discussed. The research will help provide benefits to teachers and students learning through 3D objects using AR apps in the 7E learning model. As it combines the best aspects of the digital and physical worlds, augmented reality develops distinctive digital experiences.

This paper is organized as follows: Section No.2 is about background knowledge of the topic, including updates. In Section No.3, the proposed methodology of the topic using Pre-test & Post-test techniques to study through the AR model for secondary school students with improved user experience is explained. Section No.4 comprises Results and Discussions. Section No.5 will conclude the studies, and Section No.6 is about References.

2. LITERATURE REVIEW

This section discussed the use of AR-based applications for secondary school students (SSS) in education to improve students' learning skills. It also includes the concepts of AR using the CLT model to enhance user experience, motivation, conceptual understanding, attention, creative thinking, and problem-solving. AR explores creative projects on learners, fostering creativity and motivation. Data can be collected from a scale study, motivational surveys, and an AR student survey [12]. Unity 3D Platform and Vuforia Software Development Kit (SDK) are used for pre-school children in augmented education. The 3D concept is commonly used in practical subjects like geometry, biology, chemistry, etc. [13]. Using AR tools improves the average marks of correct answers significantly, from 13% in the pre-test to 71% in the post-test. Fifteen minutes is too short for effective training to develop spatial reasoning skills, as indicated in [14]. However, using a block-building tool is encouraging, as students improved in these tests, demonstrating a demand for spatially enriched education [15].

2.1 CLT Model

In the 1960s, the National Security Agency (NSA) presented the

"Learning Cycle" model for primary school children [16]. The most basic learning cycle model of CLT is 3E. The 3E model is more efficient, and with the passage of time, researchers explored more learning models like 4E, 5E models. The researcher used the 7E CLT model in this paper. The 7E model, developed by Eisenkraft in the 2000s, was introduced because the 5E was considered inadequate for not covering certain aspects. The researcher comprehensively discussed the step-by-step stages of the 7E model in Fig 3. The 7E learning cycle model is useful in education as an instructional approach and is also recommended in science learning and teaching [11, 25].

1. Elicit: The first stage of the 7E model is elicit, with the main objective to address the prior knowledge of students.

2. Engage: The second stage of the 7E model is engage. In this stage, the teacher checks the children's attention by asking questions or showing videos about the topic and assesses the students' interest in the topic.

3. Explore: The third phase of the 7E model is explore, with the purpose of providing students with a common experience. In this stage, the teacher divides the students into different groups to explore concepts, share ideas, and communicate for better understanding.

4. Explain: In this phase, students express knowledge about the topic, discuss with their own group and other group members, and also with the teacher about their understanding of the concept, along with additional ideas. Every student in the classroom and the teacher participates and shares knowledge.

5. Elaborate: In this stage, students perform activities for a better understanding of their conceptual study. Previous knowledge helps the students ask more questions about the topic and find solutions to the problems discussed.

6. Evaluate: In this stage, the teacher evaluates the conclusions or learning outcomes provided by students. The teacher checks how well the student has learned the concept and how well they can explain it.

7. Extend: In this stage, students apply their knowledge about the concept in real-world situations by performing real-world activities. Students relate their knowledge to real-world problems and find solutions.

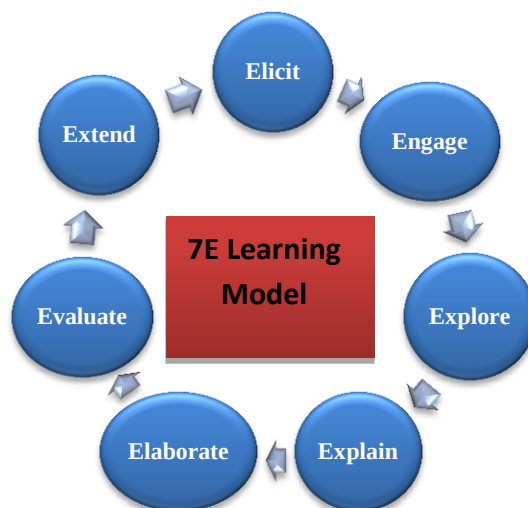
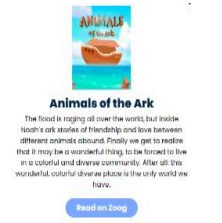
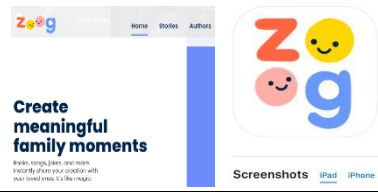
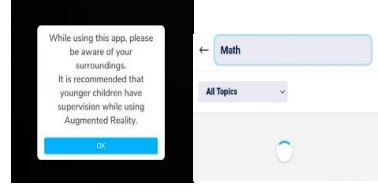


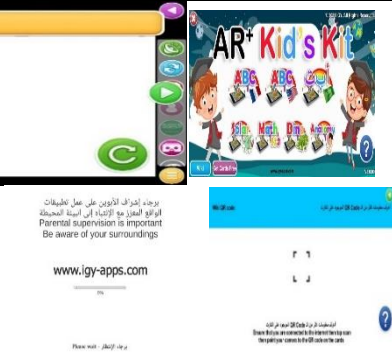
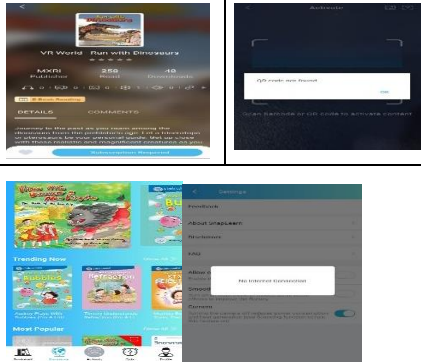
Fig 3. 7E Learning Cycle Model

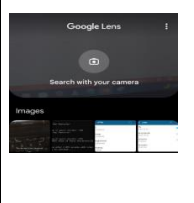
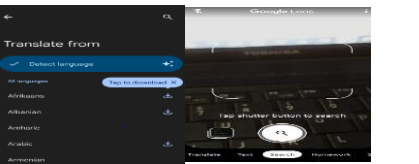
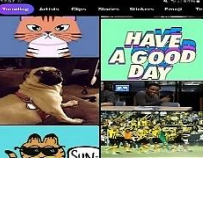
2.2 Mobile Augmented Reality applications

Mobile applications play a crucial role in education and represent a significant area of Human-Computer-Interaction (HCI) research [26]. While many researchers use traditional methods to evaluate the usability of mobile apps, these approaches are not always suitable for all mobile apps and screens [27]. In this study, the researcher employed heuristics evaluation to assess the usability of mobile apps and provided an overview in Table 1. The research focused on several AR apps available on the Google Play Store, such as Zoog, Assembler Edu, Learn 3D and AR, AR Kids Kit, BBC Civilization AR, Snap Learn: AR Books & VR World, Google Lens, and GIPHY World. The researcher applied Jacob Nielsen's ten usability points to evaluate these apps and documented both positive and negative aspects in Table 1, accompanied by pictures.

Table 1: Mobile Augmented Reality Applications

Sr. No.	AR apps	Play Store	Android or IOS	Description	Strengths	Limitations	Pictures
1	Zoog	Yes (iPad)	IOS	Zoog is a visual communication platform that enables family members to interact in a fresh and fun way. By using Zoog, anyone can read stories, sing songs, and create stunning videos.	- User Reads and write easily. - Many stories are available for children.	- No menu list or dropdown menu is available. - Only iPhone or iPad users can use this app. - Android users are unable to use this app. - When we click on any story to read on Zoog, it does not play or work. - Many social media links are used in the app that are not needed in this children's level app.	
							
2	Assembler EDU: Learn in 3D & AR	Yes	Both	Assembler EDU is the one-stop platform for students and teachers to enjoy learning in 3D and Augmented Reality (AR). With the assistance of Augmented Reality (AR) technology, teachers can deliver interactive lessons in 3D, incorporating photos, videos, and text within minutes.	- Easily create, edit, and join classes. - A popup notification always appears when we open a new window.	- The search option does not work properly. - When we click on the select button, the mobile hangs after clicking. - The video download option is not available.	
							

3	AR Kid's Kit	Yes	Both	The AR Kid's Kit application supports both virtual reality technology and augmented reality technology. It is compatible with both virtual reality glasses and a virtual reality remote, allowing users to interact with 3D models and objects.	- Stimulates the child's mind and encourages discussion. - Supports two languages.	- The app lacks an icon name, making it difficult for parents and kids to understand. - The app supports only two languages: English and Arabic. - Two different devices are required to use this app—one for scanning the cards and the second for displaying the cards.	
4	BBC Civilization AR	Yes	Both	AR has made big leaps when it comes to education, which is one of the best uses of technology. Because of these kinds of apps, AR is becoming a centerpiece in modern education	- This app is informative and helps users build interest in exploring various topics. - The app is attractive as it provides a 3D tool for learning.	- The menu is not in dropdown form; it is displayed in a globe. - It takes too much time for processing. - It does not work in offline mode.	
5	Snap Learn: AR Books & VR World	Yes	Both	Snap Learn: AR Books & VR World bring Reading and Learning to Life with Augmented Reality (AR)! STEM - Visualize abstract concepts with interactive 3D Models.	This app is informative and user friendly.	- It does not work in offline mode; it always requires an internet connection. - Most good books require a subscription. - It does not recognize QR codes. - There is no dropdown menu list for books in this app.	

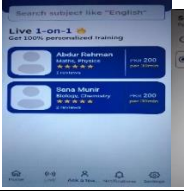
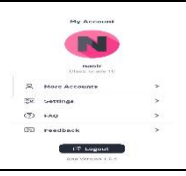
6	Google Lens	Yes	Android	Google Lens enhances the search experience. Instead of typing in a text-based query, open the app and aim it at what you want to learn more about. Google Lens will identify the object, tell you what the text says, and even store important numbers.	This app acts as helper for homework.	- There is no option to go back to the home page or select a menu. - There is no option for offline language availability; it always requires an internet connection. - Most icons are not used in this app, and many do not work properly.	  
7	GIPHY World	Yes	Android	This app combines animated GIFs and AR, transforming photos and videos into canvases for 3D graphics, much like Snapchat does. Enhance product photos by adding graphics and animated elements to give them extra flair for a social audience.	- GIPHY World performs tasks accurately. - User-friendly; new users can easily understand its features.	- Giphy mostly takes too much time during loading. - One limitation is that Giphy does not support content from other nations, creating problems when searching for non-supported content.	  

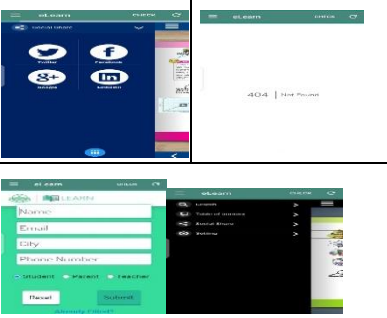
2.3 Role of AR in Education

Mobile learning and electronic learning are employed in education for both offline and online study [20]. Teachers consider it beneficial to teach from books and subsequently instruct children to scan the content using AR technology. This approach is compared to the traditional method where teachers initially used PowerPoint presentations (PPT) before integrating AR technology, and the results are then compared [21]. AR plays a crucial role in education, contributing to the application of technology and enhancing the learning experience. However, it is noted that AR user interface software may only support specific mobile or web-based screens and specific languages, limiting its applicability for students in different countries [22]. MAR applications, software, and technology are utilized both offline and online in various settings, incorporating desktop displays, cameras, GPS sensors for location, smart glasses for 3D views, smartphones, and tablets to merge real-world environments with digital content [23]. This study specifically discusses the use of AR in spatial education, focusing on different levels of special education, particularly at the primary level [24].

The researcher extensively studied various educational apps used in Pakistani schools, including popular private school apps and those used in government schools. Educational applications play a significant role in education and are a critical area of Human-Computer Interaction (HCI) research [26]. The researcher applied Jacob Nielsen's ten guidelines for usability testing to evaluate the educational apps and documented both positive and negative points in Table 2, accompanied by pictures.

Table 2 Pilot Study of Educational Apps

Sr. No.	Educational Apps	Play Store	Android or IOS	Strengths	Limitations	Pictures
1	Edkasa App	Yes	Both	Edkasa app helps you with your education by providing easy-to-follow video lectures, thousands of practice questions, notes	- Every time pin code required for login. - There are mistakes in physics portion MCQs. - Loading lectures problem face in app. - When we click on live lecture, the output or time table for live lecture does not appear. - This app is not free, tutor demands 200 PKR per 30 min lecture. - Urdu language option available but does not work.	   
2	Beacon-house App	Yes	Both	View school attendance, reports, and even participate in their achievements and special school events.	- This app is exclusively for registered Beacon House students. - The search option does not work properly. - A popup notification always appears when we open a new window. - Clicking on the logout option and then logging in again creates issues. - The student view, including challan form and attendance, is not meant for studying within the app.	   
3	Tele-school Pakistan	Yes	Both	Create an app for the Ministry of Federal Education to offer free digital learning for	- Video playback issues, with extensive buffering and inconsistent smooth operation; some chapters are incomplete. - Titles do not match their respective videos.	 

				students in Pakistan, accessible anywhere and anytime.	- No option to download videos is available. - User login problems, poor class management, and it is not user-friendly for new users.	
4	Noon Academy	Yes	Both	Friends and teachers use it for fun quizzes, practice questions, and informative learning material.	- When we log in, the app prompts us to choose a class. Upon selecting a class, the app restricts access to materials from that specific class; materials from other classes are not visible. Only recorded lecture videos are available. - This app is not suitable for children because it involves dealing with coins. Users need to earn coins before accessing study materials or other features. - Clicking on the quiz option redirects the app to the Play Store to download a separate quiz competition app.	 
5	e-Learn App	Yes	Both	This e-Learn app serves as an official repository for digitized textbooks developed under the national curriculum	- This app is designed for government sectors. - The back and side buttons do not work properly. - Writing is not supported with video. - Clicking on social media links does not work properly. - Each time, there is a need to enter name, email, city, and phone number for login.	

Previous studies have explored various working models and methods for conducting pre-test and post-test procedures to understand the impact of AR technology on student learning across multiple disciplines or workplaces. Analyzing data collected from teachers indicates that teachers should focus on adapting their teaching styles to leverage AR, providing an environment for students to develop working techniques and digital problem-solving skills through technology. The researcher extensively studied numerous Pakistani educational apps and mobile augmented reality applications, identifying various flaws documented in the tables above. However, when both educational and AR apps were used in conjunction, there was an observable increase in children's learning, as discussed in the subsequent sections. Referencing and building upon previous work using AR technology is an effective strategy to promote and enhance teacher vision and student learning. Past studies focusing on young children achieved an average of 60-70% post-test results using AR technology. The researcher aimed to improve post-test results by implementing an AR-based model for secondary school students, enhancing the overall user experience.

2.4 Problem Statement

Based on the study findings and literature review, the researcher identified various gaps and major barriers in education, including a lack of faculty, a poor educational system, insufficient concept support, limited school research, reliance on book-based learning without practical labs, and inadequate use of technology in education. The examination of many Pakistani educational apps revealed several flaws, as outlined in Table 2. When students enter school, they may face challenges in learning due to outdated teaching methods relying on pictures and books, neglecting the use of technology. Practical learning becomes difficult as many schools and colleges lack proper labs. Recognizing that today's students are inclined to use technology, the researcher capitalized on this interest, teaching children to utilize technology effectively. The results indicated that this approach made reading and searching easier, demonstrating improved outcomes. The researcher also conducted pilot studies on various AR apps, revealing that many apps are country and language-specific, often paid, and not universally helpful. Addressing these shortcomings, the researcher developed an AR-based model for both international and local users, consolidating them on a single platform. When educational and AR apps were used together, children's learning showed improvement. The researcher transitioned from traditional teaching methods to digital teaching, implementing the proposed AR model to enhance the user experience.

Research Questions

RQ: To what extent AR apps to supplementary teaching materials is more convenient for students in schools?

Sub RQ1: Do MAR apps can help to improved user experience and affect their 21st century learning and innovation skills?

Sub RQ2: What are the opinions of school students and classroom teachers on AR apps?

Sub RQ3: What do you think about MAR applications performed in public and private sectors? Compare the results between both sectors.

3. RESEARCH METHODOLOGY

The research methodology focused on evaluating students' learning through both traditional methods and an AR-based model. The approach employed a mixed methodology, incorporating both qualitative and quantitative methods to provide a comprehensive analysis. Quantitative data was gathered through the Pre-test & Post-test technique, while qualitative data was collected through semi-structured interviews using questionnaire forms. The results were presented and analyzed in the form of tables to showcase the differences between the tests. The research sample consisted of high school students from four different schools, with two schools from the government sector and two from high-rated private sectors. The data collection occurred during the 2022-2023 academic session, involving a minimum of one hundred sixty (160) students from both public and private sectors. The age range of the students was between 11 and 16 years old.

3.1 Study Instrument

To evaluate the performance and learning of students and assess their learning capability and interests, the research instrument comprised two tests: the Pre-Test and Post-Test. The Pre-Test served as an achievement and attitude test, incorporating both open and closed-ended questions. This test was administered to all four schools, and the data results were collected and saved. Subsequently, teachers focused on using AR apps to enhance the best use of technology in education, with an emphasis on the 7E CLT model. After teaching students with AR technology, the Post-Test, including an achievement and attitude scale test towards AR apps, was administered. The results were collected, saved, and then compared. The research methodology also included obtaining feedback through a semi-structured interview form from teachers, students, and the local public to further enhance the understanding of the Research Methodology and its impact on student learning. In this research, the attitude scale towards AR technology and the achievement test consisted of a mixture of open-ended and closed-ended questions related to the topics of change of states in Physics, the periodic table in Chemistry, and the human skeleton system in Biology. The Post-Test results were gathered as quantitative data, while qualitative data were collected using a semi-structured interview form from teachers, students, and parents. The research pattern has been outlined in Table 3.

Table 3 Research Pattern

Pre-Test	Application	Post-Test
Achievement Test with Open-Ended & Closed-Ended Questions.	Augmented Reality	Achievement Test with Open-Ended & Close-Ended Questions.
Attitude Scale Test towards AR technology.	Applications	Attitude Scale Test towards AR Technology.
		Semi-Structured Interview Form

3.2 Implementation and Procedure

3.2.1 Proposed AR Based Model

The researchers developed an AR-based model titled "AR in Education," and its flow diagram is depicted in Fig. 4. When the user opens the app, the first page displays four menus: Features, Plans, Login, and Signup. If the user already has an account, they can log in; otherwise, they need to sign up first and then log in successfully. Upon logging in, the user encounters the main page of the application, featuring various menus such as Home, Grades, Topics, Class, and Help. Clicking on the Grades menu reveals classes from KG to 12, allowing the user to select the desired option. Upon choosing a grade, different subjects for that grade are displayed, allowing the user to explore any lesson at their discretion. Users can view 3D & AR images during their study and play videos related to the lesson. The app enables users to create a class or join a class by sharing a link or scanning a code, a feature not present in other AR apps studied. This menu caters to both teachers and students, providing a user-friendly experience. An additional notable feature is the language selection option, which was not available in other apps. This feature proves beneficial for users from various countries, enhancing the educational experience. The three-line function on the left side of the app offers various options, as depicted in the image. The main function is the AR camera. When the user clicks on the AR camera, two more options appear: marker-less and marker-based. Users can select either option to take a picture with the camera. If marker-based is chosen, the app compares the image with the database and displays the result. On the other hand, if marker-less is selected, the app presents the image in AR view using feature detection.

3.2.2 Research Methodology

In the Research Methodology Fig. 5 researchers taken students from four different schools and collect data of one hundred sixty (160) students with different mind level and attitude. Every school class was divided into two groups with named control group and other one is experimental group with equal number of students. In “School-A” randomly selected of 40 students, twenty of them randomly selected for the control group and remaining twenty for experimental group. Similarly “School-B”&“School-C”&“School-D”selected of 40 students.

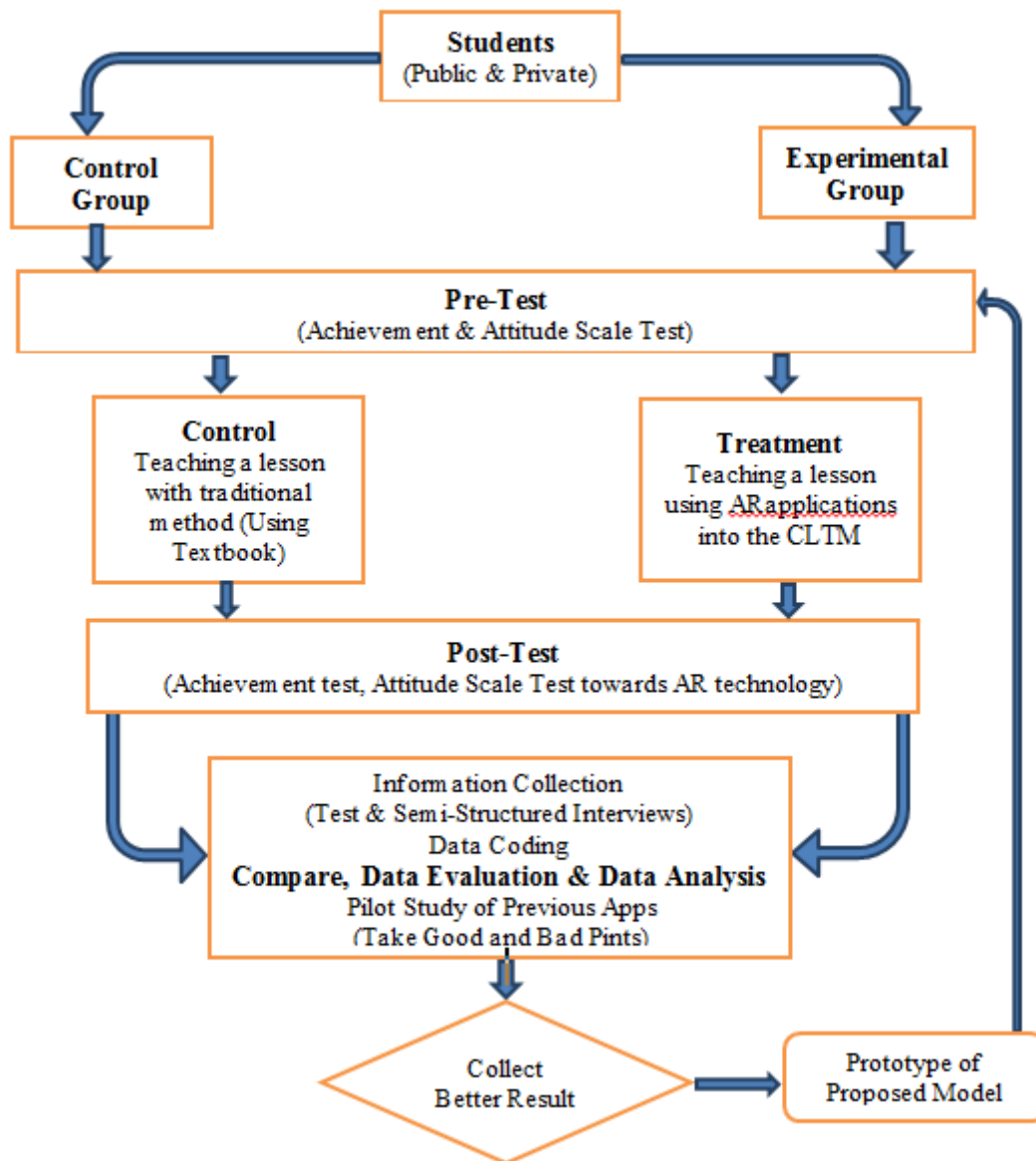


Fig. 5: Research Methodology

3.2.3 Work Flow and Application Process

In the first week of the study, teachers assessed the performance of students by conducting the Pre-Test for all students from the four schools, recording the findings as results in the form of their marks. The second week, dedicated to the Workflow and Application Process, involved teaching students study instructions and introducing them to the use of augmented reality on mobile phones, smartphones, and tablets. All students were instructed to access the apps via Wi-Fi or mobile networks, as guided by the instructor at the study's commencement. In the third week, teachers first taught the control group students using traditional teaching methods, such as textbooks, and collected data as achievement and attitude Post-Test, saving the data in tabular form. On the other side, teachers taught the experimental group students with AR apps, focusing on the best use of technology in education to enhance user experience. Teachers assessed the performance of students using the AR-based model with the help of the Constructivist Learning Theory Model (CLTM). Teachers facilitated brainstorming sessions for students and encouraged them to engage in active learning through group activities using AR apps, creating a conducive environment for asking questions and sharing information and ideas with others. After teaching students using AR apps with the help of CLTM and employing traditional teaching methods for both groups, teachers assigned tasks on topics of biology, physics, and chemistry for both groups. While students from the control groups explored the same objects using traditional methods with textbooks and pictures, students from the experimental groups used smartphones/tablets with AR apps to complete the tasks. The completion of the biology task using the augmented reality app is shown in Fig. 6, the physics task in Fig. 7, and the chemistry task in Fig. 8.

Alternative Hypothesis (H_1)

(H_1) **RQ:**AR apps are convenient for students in schools to supplement teaching material.

(H_1) **Sub RQ:**MAR apps help to improved user experience and affect their 21st century learning and innovation skills.

(H_1) **Sub RQ:**There is significant difference in achievement of both public and private sectors using AR technology.

4. RESULTS and DATA ANALYSIS

To collect and analyze the data that taking through pre-test and post-test using individually and combine AR technology apps and constructivist learning theory model. The researcher calculated the mean and standard deviation using SPSS software.

Table 5Pre-Test and Post-Test Results of **School- A**

Strategy/Treatment	Subject	Pre-Test			Post-Test			LOG
		NOS	Mean	SD	NOS	Mean	SD	
Traditional Way (Book) (Control Group)	Biology	20	4.25	2.040	20	11.60	3.160	36.8%
	Physics	20	4.55	2.282	20	11.55	2.874	35.0%
	Chemistry	20	3.90	2.075	20	11.60	1.759	38.5%
AR (Experimental Group)	Biology	20	4.8	2.092	20	15.05	2.564	51.3%
	Physics	20	4.6	2.501	20	13.30	3.526	43.5%
	Chemistry	20	4.8	2.167	20	13.90	2.553	45.5%

NOS: No. of Students, SD: Standard Deviation, LOG: Learning Outcomes Gains

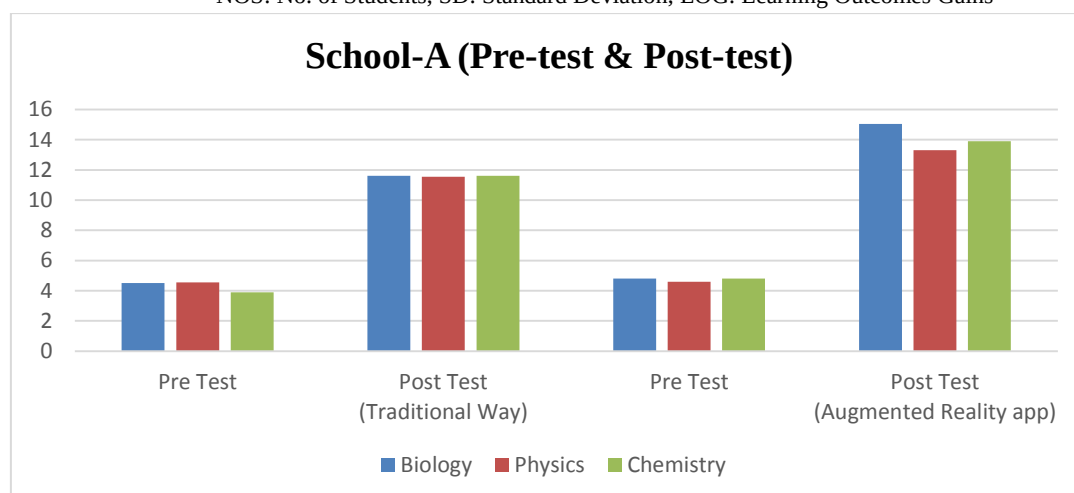


Fig 9: Bar Graph Result Representation of School-A

Table 5, graphically represented in Fig. 9, displays the results of tests for School-A in tabular form for both Pre-Test and Post-Test. The findings suggest that the traditional method is less effective compared to AR technology. In the post-test results, the experimental group shows better learning outcomes than the results of the post-test conducted using traditional methods.

Table 6: Pre-Test and Post-Test Results of **School- B**

Strategy/Treatment	Subject	Pre-Test			Post-Test			LOG
		NOS	Mean	SD	NOS	Mean	SD	
Traditional Way (Book) (Control Group)	Biology	20	4.00	2.050	20	9.5	3.440	27.5%
	Physics	20	3.80	2.330	20	10.2	3.968	32%
	Chemistry	20	3.50	2.164	20	9.9	3.523	32%
AR (Experimental Group)	Biology	20	3.45	2.064	20	15.25	2.712	59%
	Physics	20	3.60	2.303	20	14.15	3.617	52.8%
	Chemistry	20	3.15	2.390	20	14.70	2.577	57.8%

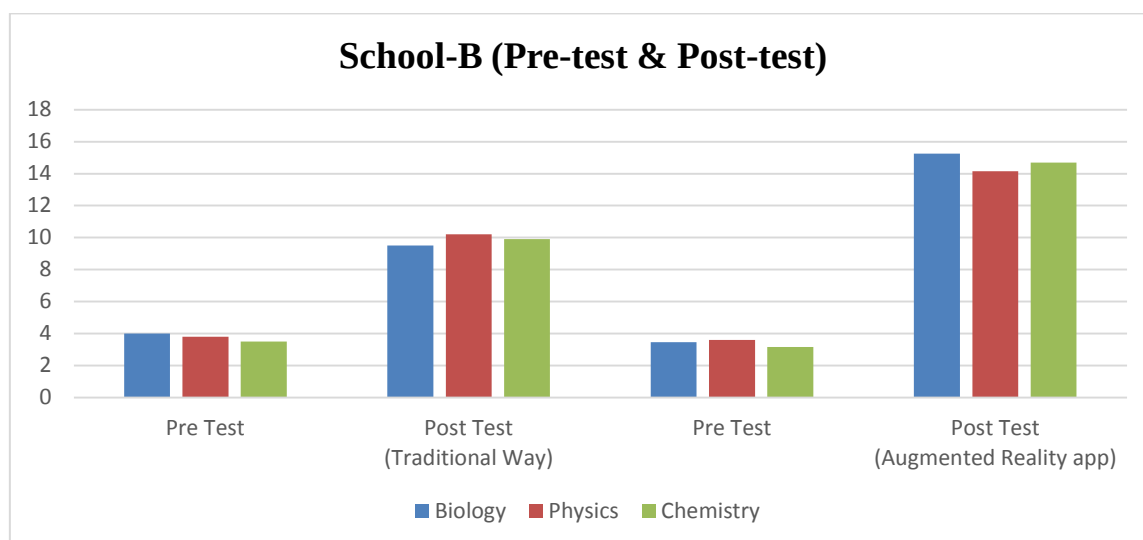


Fig 10: Bar Graph Result Representation of School-B

The Table 6 which is graphically represented in Fig 10 shows that AR technology with 7E learning model gave better result when we use these in classroom. In post-test results of experimental group gain learning outcomes better than results of post-test of traditional way. 59%, 52.8% & 57.8% learning outcomes gains in post-test results.

Table 7: Pre-Test and Post-Test Results of School- C

Strategy/Treatment	Subject	Pre-Test			Post-Test			LOG
		NOS	Mean	SD	NOS	Mean	SD	
Traditional Way (Book) (Control Group)	Biology	20	3.40	2.604	20	10.30	4.131	34.5%
	Physics	20	3.05	2.139	20	10.60	3.966	37.8%
	Chemistry	20	3.15	1.663	20	10.90	4.278	38.8%
AR (Experimental Group)	Biology	20	3.20	1.936	20	14.55	3.990	56.8%
	Physics	20	3.90	2.292	20	14.75	3.007	54.3%
	Chemistry	20	3.45	2.139	20	15.15	3.528	58.5%

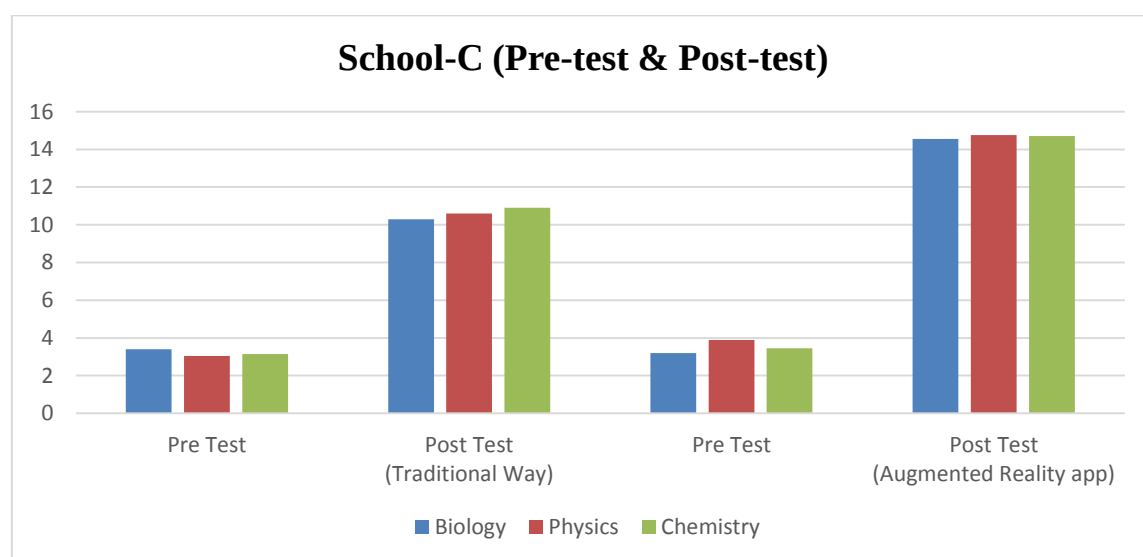


Fig 11. Bar Graph Result Representation of School-C

Table 7, graphically represented in Fig. 11, illustrates that utilizing AR technology is valid and applicable in schools for better results. In the post-test results, the experimental group achieved better learning outcomes compared to the post-test results of the traditional method. There were gains of 56.8%, 54.3%, and 58.5% in learning outcomes in the post-test results.

Table 8: Pre-Test and Post-Test Results of **School- D**

Strategy/Treatment	Subject	Pre-Test			Post-Test			LOG
		NOS	Mean	SD	NOS	Mean	SD	
Traditional Way (Book) (Control Group)	Biology	20	3.45	2.837	20	9.650	4.344	31.0%
	Physics	20	3.60	2.741	20	10.30	4.438	33.5%
	Chemistry	20	3.35	2.815	20	10.00	4.634	33.3%
AR (Experimental Group)	Biology	20	3.15	2.033	20	16.05	2.523	64.5%
	Physics	20	3.30	2.319	20	15.80	1.989	62.5%
	Chemistry	20	2.30	1.838	20	16.35	3.048	70.3%

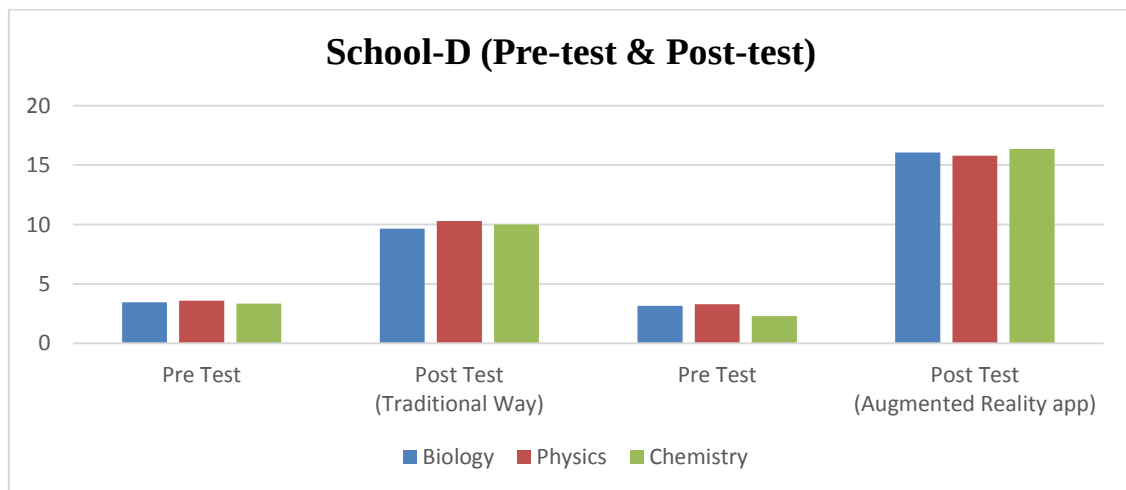


Fig 12. Bar Graph Result Representation of School-D

Table 8, graphically represented in Fig. 12, indicates that in the post-test results, the experimental group achieved better learning outcomes compared to the post-test results of the traditional method.

4.1 Hypothesis Testing

The researchers employed a hypothesis test to evaluate whether the difference between the two samples accurately reflects the true difference between the results from where the samples were taken. A null hypothesis of no difference serves as the starting point, and the probability that both sets of data originate from the same source is calculated. The significance level is set at 0.05 (5%), indicating a 5% risk of concluding that a difference exists when there is no actual difference in pre-test and post-test results.

This approach was applied to the academic achievement results of the four aforementioned schools (private and government sectors). A 5% (0.05) chance implies the rejection of the null hypothesis, while a 95% confidence level is established for accepting the null hypothesis. Additionally, a one-tailed (directional hypothesis) test for a one-sided distribution was applied. The critical value on the one-tailed test is 1.686 when the degree of freedom is 38 and the significance level is 0.05.

4.1.1 Testing of First Null Hypothesis (H_0) for School-A

AR apps are not convenient for students in schools to supplement teaching materials. To test the above hypothesis, the pre-test& post-test of the students were using as covariates, this reflect in Table 9.

Table 9: T-Test Results for Achievement Test Scores of **School- A**

Variable	Subject	Test	NOS	Mean	SD	t (40)	P (value)
Academic achievement (Experimental Group)	Biology	Pre-test	20	4.8	2.092	-13.849	.000
		Post-test	20	15.05	2.564		
	Physics	Pre-test	20	4.6	2.501	-09.001	.000
		Post-test	20	13.3	3.526		
	Chemistry	Pre-test	20	4.8	2.167	-12.155	.000
		Post-test	20	13.9	2.553		

Table 9 indicates for School-A that $t(40) = -13.84929$, $p = .00001$ for biology, $t(40) = -9.001$, $p = .00001$ for physics, and $t(40) = -12.155$, $p = .00001$ for chemistry. All results are significant at $p < 0.05$, indicating rejection of the null hypothesis. Therefore, the alternative hypothesis (H_1) is accepted: AR apps are convenient for students in schools to supplement teaching material.

4.1.2 Testing of Second Null Hypothesis (H_0) for School-A

MAR apps cannot help improve user experience and affect 21st-century learning and innovation skills. The results above are significant at $p < 0.05$, indicating rejection of the null hypothesis. Therefore, the alternative hypothesis (H_1) is accepted: MAR apps help improve user experience and impact 21st-century learning and innovation skills.

4.1.3 Testing of First Null Hypothesis (H_0) for School-B

AR apps are not convenient for students in schools to supplement teaching materials. To test the above hypothesis, the pre-test & post-test of the students were used as covariates, as reflected in Table 10.

Table 10: T-Test Results for Achievement Test Scores of **School- B**

Variable	Subject	Test	NOS	Mean	SD	t (40)	P (value)
Academic achievement (Experimental Group)	Biology	Pre-test	20	3.45	2.064	-15.484	.000
		Post-test	20	15.25	2.712		
	Physics	Pre-test	20	3.6	2.303	-11.003	.000
		Post-test	20	14.15	3.617		
	Chemistry	Pre-test	20	3.15	2.390	-14.695	.000
		Post-test	20	14.7	2.577		

Table 10 indicates for School-B that $t(40) = -15.48363$, $p = .00001$ for biology, $t(40) = -11.00307$, $p = .00001$ for physics, and $t(40) = -14.69505$, $p = .00001$ for chemistry. Thus, all results for School-B are significant at $p < 0.05$. This means the null hypothesis is rejected, and the alternative hypothesis (H_1) is accepted: AR apps are convenient for students in schools to supplement teaching materials.

4.1.4 Testing of Second Null Hypothesis (H_0) for School-B

MAR apps cannot help to improve user experience and affect their 21st-century learning and innovation skills. The above results are significant at $p < 0.05$, which means the null hypothesis is rejected, so the alternative hypothesis (H_1) is accepted: MAR apps help to improve user experience and affect their 21st-century learning and innovation skills.

4.1.5 Testing of First Null Hypothesis (H_0) for School-C

AR apps are not convenient for students in schools to supplement teaching materials. To test the above hypothesis, the pre-test & post-test of the students in the form of mean & standard deviations were used as covariates, as reflected in Table 11.

Table 11: T-Test Results for Achievement Test Scores of **School- C**

Variable	Subject	Test	NOS	Mean	SD	t (40)	P (value)
Academic achievement (Experimental Group)	Biology	Pre-test	20	3.2	1.936	-11.438	.000
		Post-test	20	14.55	3.99		
	Physics	Pre-test	20	3.9	2.292	-12.835	.000
		Post-test	20	14.75	3.007		
	Chemistry	Pre-test	20	3.45	2.139	-12.681	.000
		Post-test	20	15.15	3.528		

Table 11 indicates for School-C that $t(40) = -11.43839$, $p = .00001$ for biology, $t(40) = -12.83502$, $p = .00001$ for physics, and $t(40) = -12.68062$, $p = .00001$ for chemistry. All results for School-C are significant at $p < 0.05$, meaning the null hypothesis is rejected, and the alternative hypothesis (H_1) is accepted: AR apps are convenient for students in schools to supplement teaching material.

4.1.6 Testing of Second Null Hypothesis (H_0) for School-C

MAR apps cannot help improve user experience and affect their 21st-century learning and innovation skills. The above results are significant at $p < 0.05$, which means the null hypothesis is rejected. Therefore, the alternative hypothesis (H_1) is accepted: MAR apps help to improve user experience and affect their 21st-century learning and innovation skills.

4.1.7 Testing of First Null Hypothesis (H_0) for School-D

AR apps are not convenient for students in schools to supplement teaching materials. To test the above hypothesis, the pre-test & post-test of the students were using as covariates, this reflect in Table 12.

Table 12: T-Test Results for Achievement Test Scores of **School- D**

Variable	Subject	Test	NOS	Mean	SD	t (40)	P (value)
Academic achievement (Experimental Group)	Biology	Pre-test	20	3.15	2.033	-17.804	.000
		Post-test	20	16.05	2.523		
	Physics	Pre-test	20	3.3	2.319	-18.295	.000
		Post-test	20	15.8	1.989		
	Chemistry	Pre-test	20	2.3	1.838	-17.652	.000
		Post-test	20	16.35	3.048		

Table 12 indicates for **School-D** that $t(40) = -17.80369$, $p = .00001$ for biology, $t(40) = -18.29469$, $p = .00001$ for physics and $t(40) = -17.65164$, $p = .00001$ for chemistry. Thus all results are significant at $p < 0.05$ this means null hypothesis is rejected, so alternative hypothesis (H_1) is accepted: AR apps are convenient for students in schools to supplement teaching material.

4.1.8 Testing of Second Null Hypothesis (H_0) for School-D

MAR apps cannot help to improved user experience and affect their 21st century learning and innovation skills. At above results are significant at $p < 0.05$ this means null hypothesis is rejected, so alternative hypothesis (H_1) is accepted: MAR apps help to improved user experience and affect their 21st century learning and innovation skills.

4.1.9 Comparison between Public and Private Sectors Results and Testing of Third Null Hypothesis (H_0)

In testing hypothesis, the public and private sectors student's scores taught with AR were tested with t-test statics to compare the mean, standard deviation reflected in Table 13.

Table 13: T-Test Results of both Public and Private sectors

Variables	Schools	NOS	Df	Mean	SD	t(80)	Sig. (two-tailed)
Public	School-A School-B	40	78	43.18	5.084	-2.548	.012805
Private	School-C School-D	40		46.33	5.811		

Table 13 indicates for both public and private sectors that $t(80) = -2.54783$, $p = .012805$ when we apply two-tailed hypothesis but when we apply one-tailed hypothesis so p value is .006403. SEM (standard error of the mean) for public is 0.803809 and variance is 25.844 for data of both public schools and SEM (standard error of the mean) for private is 0.918822 and variance is 33.769 for data of both private schools. Thus all results are significant at $p < 0.05$ (.012805 < 0.05) this means null hypothesis (H_0): There is no significant difference in achievement of both public and private sectors using AR technology is rejected, so alternative hypothesis (H_1): There is significant difference in achievement of both public and private sectors using AR technology is accepted.

4.2 Results of Attitude Scale Test towards AR Technology

Researcher collected these results from eighty (80) students of experimental group that are using technology related AR apps. The student's scores on the attitude towards digital AR technology were analyzed by taking test and examine the results in Fig. 13.. Figure 13 has been shown results in the form of percentage.

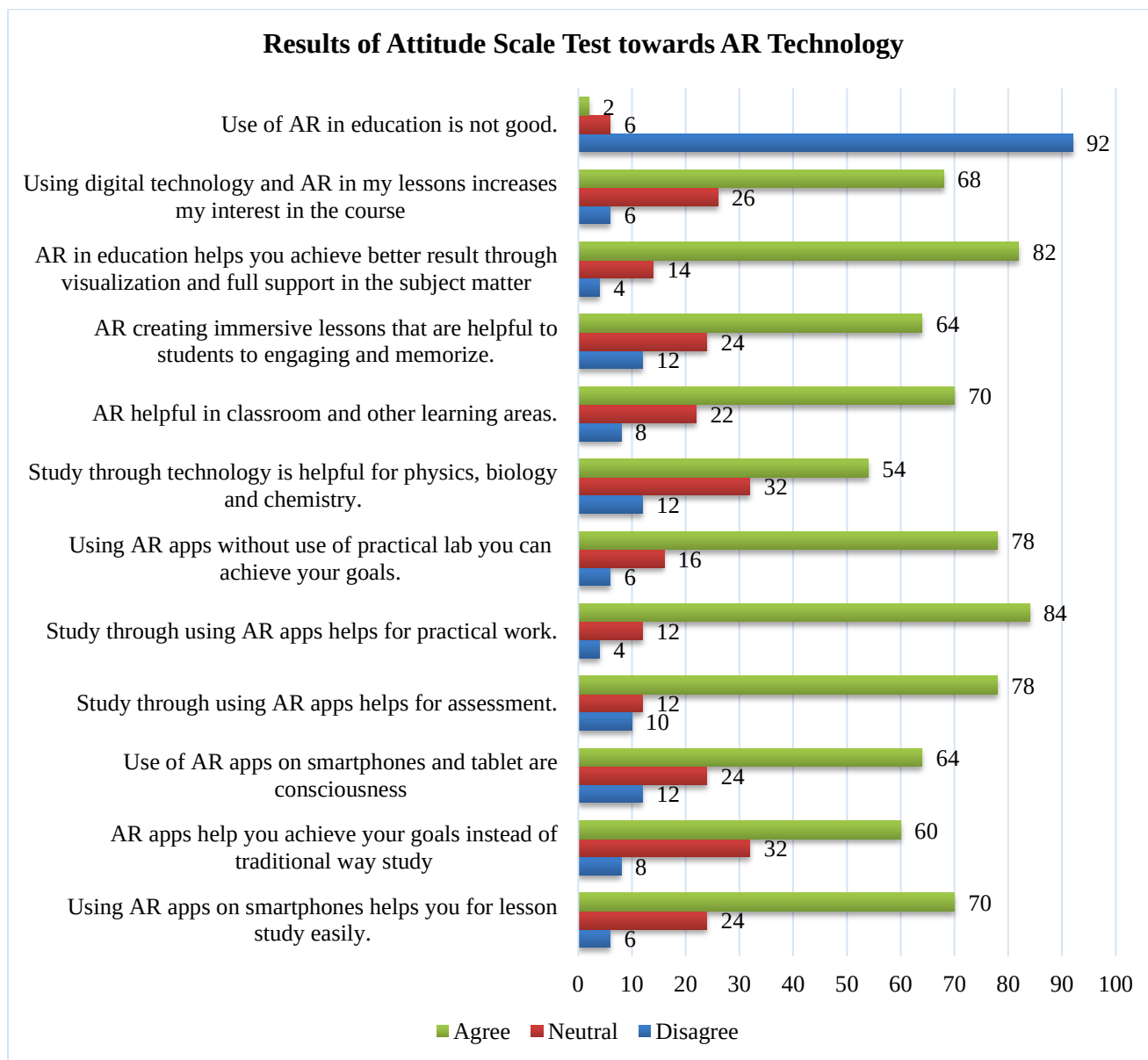
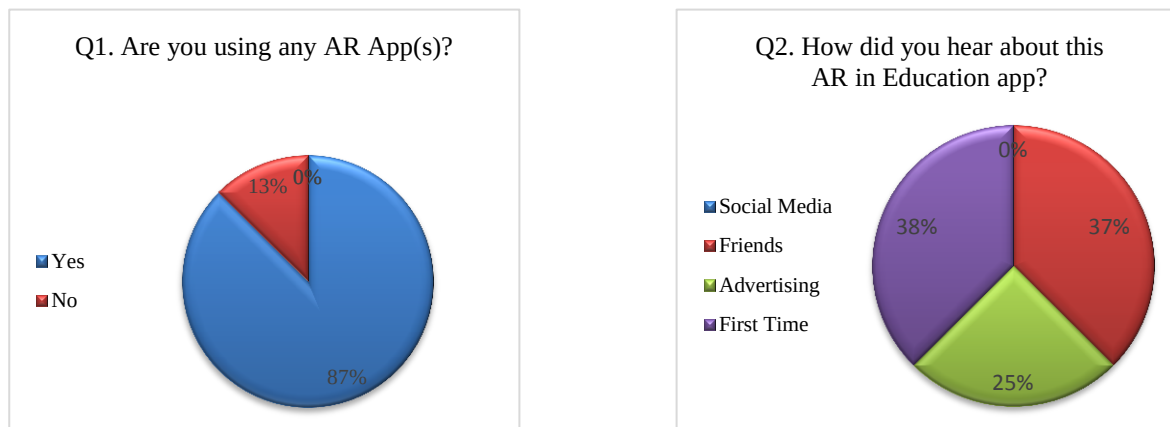


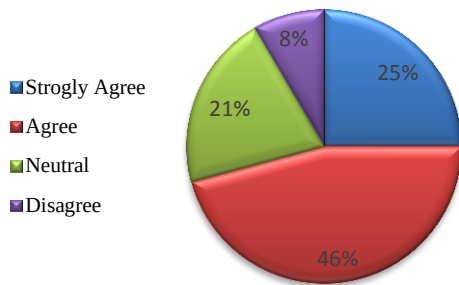
Fig 13. Bar Graph Result of Attitude Scale Test towards AR Technology

4.3 Results of Semi-Structured Interview

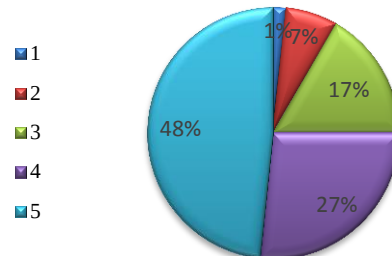
The Semi-Structured Interview Form consists of twelve questions with a mixture of descriptive and non-descriptive elements. The data were collected from different age groups and genders, including students, teachers, and others (e.g., parents). In total, data were collected from 120 respondents, including 73 students (mostly from 9th and 10th grades), 30 teachers, and 17 others. The results from the questionnaire forms are presented in graphs in Fig. 13. The majority of respondents expressed interest in AR and its usage, giving high ratings. This suggests that the AR technology method is helpful for use in the classroom, facilitating student learning and enhancing teacher performance in achieving their goals.



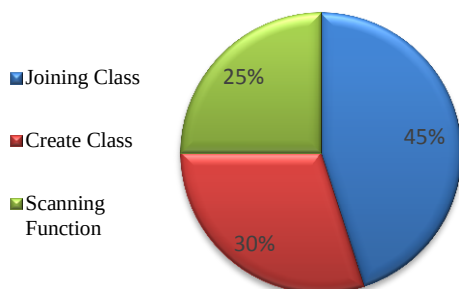
Q3. AR apps help you achieve your goals with the existing features?



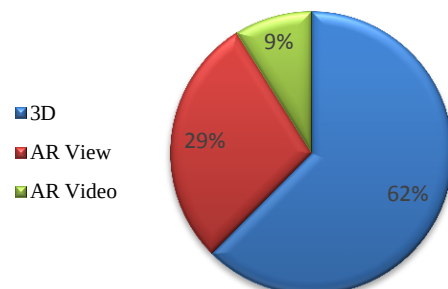
Q4. How much extent system support your overall learning?
Please Rank (1-5)



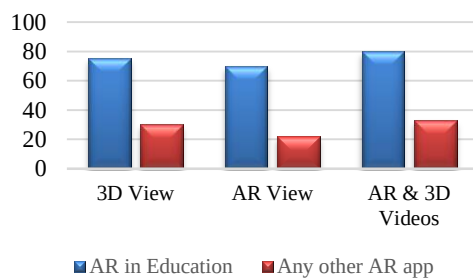
Q5. Divide 100 points between to use of these app features.



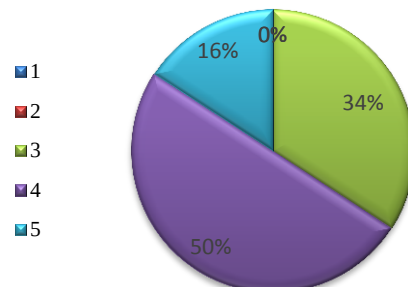
Q6. Please rate the following attributes/Functions of this app.



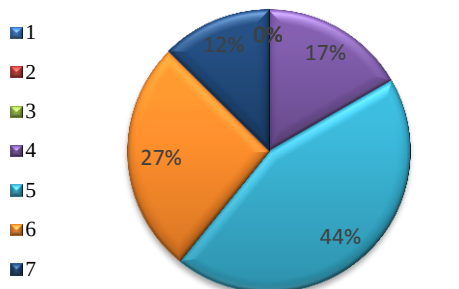
Q7. Please rate the following functions of AR in Edu app and any other app you use already.



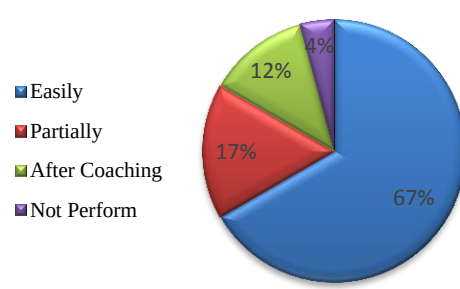
Q8. Rate your experience using this app with 1-5 starts.



Q9. Rate the interface of AR in Edu app from 1-7



Q10. How many users completed the task given by the researcher



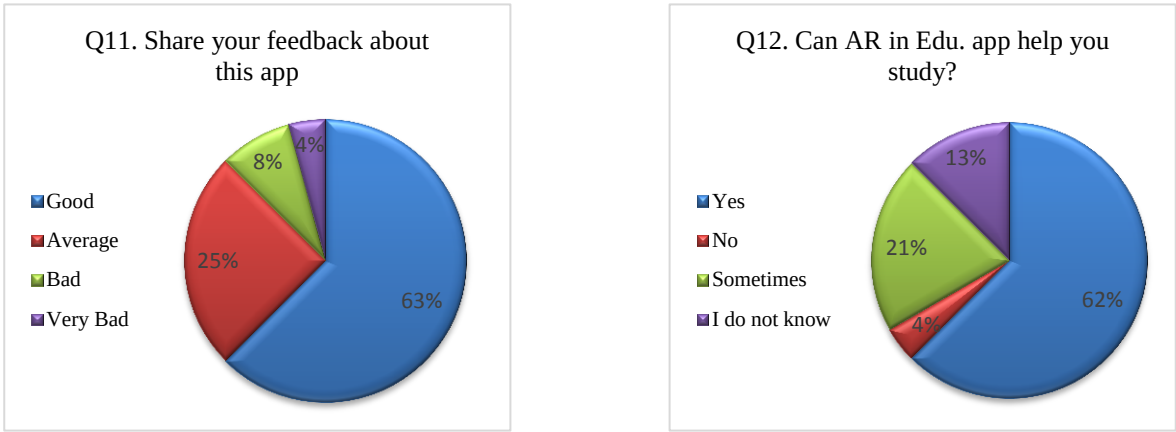


Fig 14. Graph Results of Semi-Structured Interview Form (Questionnaire

4.4 Heuristic Evaluation Results

While Nielsen's heuristics provided a simple and easily understandable framework applicable to most types of user interfaces, some usability issues were identified during the Heuristic Evaluation. Overall, the heuristics scored quite well. The usability testing and evaluation report are presented in Table 16.

Table 16 Heuristic Evaluation of “AR in Education” app

Sr. No.	H.E. Principals	Descriptions	Limitations	Pictures
1	Visibility of System Status	Active menu items are functional in this app. A cross sign is available for closing pages. Download and upload notifications are displayed for user convenience. In the topics menu, icons are shown alongside their respective pictures. In every login and signup field, details are displayed before typing, which enhances user understanding. Pagination is well-implemented.	We use the back option for previous actions. No dynamic validation exists in this app; there is an 8-digit limit, but it is not clear what type of characters are allowed. For example, if we enter any 8 numbers, the password is saved without specifying the character type.	 
2	Match between System and Real World	Icons with names are available, making it easy to understand. Text in this app is easily understandable. Icon images match with their respective names. Search option is accompanied by an icon. The categorization of naming is good.	Social media icons only display images without accompanying names.	

3	User Control and Freedom	- Users can easily create an account, login, or perform other functions such as create, read, update, and delete. - When we open an icon or category, a quit or cancel option is available in this app. - A search bar is available in this app. - Users can easily select language preferences, such as English or Urdu.	Works only in two languages: English and Urdu.	
4	Consistency and Standards	- Consistency is maintained in icons with the same size and uniform text in drop-down lists. - There is also consistency in topics icons, and the color of icons is uniform. - Photos and themes best match the content. - Input fields are of the same size with uniform text, and drop-down menu list text is also of the same size.	Some list text has different sizes in the class menu.	
5	Error Prevention	- The app provides auto-fill, auto-complete, and auto-suggest features. - Password strength options are available, such as requiring 8 digits, but confirmation messages do not appear for passwords that are too small or too long.	This app does not provide a wake-up message when transferring or receiving files or account details.	
6	Recognition rather than Recall	- Auto-search or suggestions are available in this app. - A search bar option is available. - Icons with names are present, making it easy to understand. - Icon images also aid in understanding. - Input fields include helper text. - When clicking on grade selection or other menu options, the chosen field shows with blue text. - Logout is indicated with a red color to alert before clicking.	In the search bar option, sometimes suggestion words do not appear.	

7	Flexibility and Efficiency of Use	- Shortcuts are available in this app, allowing users to sign in through Facebook, Google, and Microsoft. - Login and create account options are available for users. - A search bar option is provided. - The app assists in entering data by including input fields with dummy or helper text. - Icons are displayed with pictures and their respective names.	Some icons do not display their names.	
8	Aesthetic and Minimalist Design	- The background of the app is pleasant, using a suitable color for the background. - Education-related icons such as grades, topics, and class are available. - A search bar option is provided. - Icons and screen graphics use suitable names and sizes. - The app includes only user education-related information.	The contact menu is not displayed in this app.	
9	Help Users Recognize, Diagnose & Recover from Errors	- Clicking on the left side three lines displays the user profile, my models, 3D gallery, logout, etc., for user convenience. - If you forget the password, the app provides an option for password recovery, allowing you to set a new password or recover the existing one.	The app does not provide a notification message for an incorrect password.	
10	Help and Documentation	- Input fields include helper text for the user. - A help icon is available on the home screen. - There is a search bar option for help. - The app provides a complaints option for users. - Social media links such as LinkedIn, Facebook, and Twitter are available for speedy access to these features of the app. - Icons are displayed with pictures and their respective names.	The contact menu is not displayed in this app.	

5. CONCLUSION

Based on the research paper report and the study's findings, the methods employed to introduce AR to students, and the questionnaire data collected from students, teachers, and parents, it can be concluded that employing AR methods can lead to better results and improved learning outcomes for students. AR methods offer teachers enhanced opportunities to elucidate abstract concepts, improve their own teaching methodologies, inspire students' minds, and encourage exploration of new educational ideas. The use of AR technology apps fosters student engagement, communication, and an enhanced ability to grasp curriculum content through the integration of technology. AR apps provide substantial benefits to both teachers and students, facilitating learning through 3D objects. The research involved the quantitative analysis of data collected from various schools, encompassing both private and public sectors, utilizing pre-test and post-test methodologies with SPSS software. The analysis included t-tests, obtaining P-values with one and two-tailed hypothesis significance levels, and testing both null and alternative hypotheses. Qualitative results were also obtained through semi-structured interviews (questionnaires) directly from students, teachers, and parents. An attitude scale test towards AR technology was conducted before the post-test. When applying these methods to the government sector, less effective results were observed compared to the private sector, indicating that AR combines the best aspects of the digital and physical worlds. Notably, no specialized hardware or software is required for the AR experience. Users reported excitement and enhanced feelings, fun, and motivation when interacting with AR applications. AR encourages students to allocate more time to academic subjects using technology, reducing the time spent on social media platforms. It is noteworthy that users consistently demonstrate higher motivation levels with AR systems. The cumulative evidence from various studies affirms that AR technology enhances learning efficacy, promotes e-teaching and e-learning, and supports individualized learning in the classroom.

Future Work and Recommendation:

The study lays the foundation for various potential research avenues. Initially, validating the findings with larger datasets would contribute to the robustness of the research. Subsequent investigations could apply the same methodology to explore different subjects or novel combinations of subjects. Future studies may also delve into examining the validity of the proposed acceptability model when comparing institutions or students across different countries.

Based on the study, the following recommendations are put forth:

- Students should possess their own tablets, smartphones, or laptops.
- Encouraging students to engage in computer studies is advisable.
- Students should be made aware of how to effectively utilize the internet on tablets, cell phones, or laptops.
- Seminars should be conducted to promote awareness of the use of technology in education.
- Functional computer laboratories and multimedia facilities should be implemented in every school.

6. References

1. B. A. K. Uğur YÜZGEÇ, and Burakhan ÇUBUKÇU, (2021). "<An AR Based Mobile Education Application for Preschool Children.pdf>," vol. Volume 2, no. 1, p. 7.
2. Wikipedia,
"AR"https://en.wikipedia.org/wiki/Augmented_reality
3. "Microsoft Team, "Types of AR",
<https://dynamics.microsoft.com/enus/mixedreality/guides/whatisaugmentedreality/#:~:text=Understanding%20augmented%20reality&text=AR%20incorporates%20three%20features%3A%20a,of%20virtual%20and%20real%20objects>, (accessed Dec. 27, 2022).
4. "How Does AR Work of AR",
<https://www.digiloup.com/how-does-augment-reality-work/> July 1, 2019 (accessed Dec. 27, 2022).
5. "MAR"<https://www.igi-global.com/dictionary/enabling-training-in-orthodontics-through-mobile-augmented-reality/> (accessed Dec. 27, 2022).
6. F. Aydoğdu, (2021). "AR for preschool children: An experience with educational contents," *British Journal of Educational Technology*, vol. 53, no. 2, pp. 326-348.
7. J. Bacca-Acosta, C. Avila-Garzon, Kinshuk, J. Duarte, and J. Betancourt, (2021). "AR in Education: An Overview of Twenty-Five Years of Research," *Contemporary Educational Technology*, vol. 13, no. 3.
8. Marrahí-Gómez, V., & Belda-Medina, J. (2022). The application of augmented reality (AR) to language learning and its impact on student motivation. *International Journal of Linguistics Studies*, 2(2), 07-14.
9. G. Juan, P. Juan, B. Silvia. (2017). "AR Applications for Education: Five Directions for Future Research." *International Conference on AR, Virtual Reality and Computer Graphics*, Springer, pp. 402-414.
10. "Roots and Evolution of Learning Cycle Model in Light of Constructivist Theory-A Sample Activity -"
<http://213.14.10.181/index.php/EB/article/view/607/86> (accessed Dec. 28, 2022).
11. Erçağ, E., & Yasakçı, A. (2022). The Perception Scale for the 7E Model-Based Augmented Reality Enriched Computer Course (7EMAGBAÖ): Validity and Reliability Study. *Sustainability*, 14(19), 12037.
12. Y.-J. Lin and H.-c. Wang, (2022). "Applying AR in a university English class: Learners' perceptions of creativity and learning motivation," *Innovation in Language Learning and Teaching*, pp. 1-15.
13. Suselo, T., Wünsche, B. C., & Luxton-Reilly, A. (2021, March). Using mobile augmented reality for teaching 3D transformations. In *Proceedings of the 52nd ACM Technical*

Symposium on Computer Science Education (pp. 872-878).

14. Lowrie, T., Logan, T., & Hegarty, M. (2019). The influence of spatial visualization training on students' spatial reasoning and mathematics performance. *Journal of Cognition and Development*, 20(5), 729-751.
15. Maranto, R., & Wai, J. (2020). Why intelligence is missing from American education policy and practice, and what can be done about it. *Journal of Intelligence*, 8(1), 2.
16. Karplus, R., & Thier, H. D. (1967). A new look at elementary school science: Science curriculum improvement study. (No Title).
17. Halabiya, F. (2022). The Effect of The Brainstorming Strategy on Developing The Problem-Solving Method of AL-QUDS University Students. *Turkish Journal of Physiotherapy and Rehabilitation*, 32(3), 17276-17266.
18. Obro, S., Ogheneakoke, C. E., & Akpochofo, W. P. (2021). Effective social studies pedagogy: Effect of simulation games and brainstorming strategies on students' learning outcome. *International Journal of Learning, Teaching and Educational Research*, 20(3), 1-17.
19. F. Herpich, F. B. Nunes, G. Petri, and L. M. R. Tarouco, (2019). "How MAR Is Applied in Education? A Systematic Literature Review," *Creative Education*, vol. 10, no. 07, pp. 1589-1627,.
20. O. Michael, (2021). "Efficacy of AR as a pedagogical strategy in development of students learning of creative arts," *Journal of Educational Research, Dept. of Education, IUB*, vol. Vol. 23 No. 2, pp. 1-13.
21. Zhang, J., Yen, S. H., Liu, T. C., Sung, Y. T., & Chang, K. E. (2022). Studies on learning effects of ar-assisted and ppt-based lectures. *The Asia-Pacific Education Researcher*, 31(1), 1-10.
22. Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, 9(3), 136-148.
23. Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2022). User acceptance of augmented reality welding simulator in engineering training. *Education and Information Technologies*, 27(1), 791-817.
24. A. Kapetanaki, A. Krouska, C. Troussas, and C. Sgouropoulou, (2022). "Exploiting AR Technology in Special Education: A Systematic Review," *Computers*, vol. 11, no. 10.
25. S. Rahman, R. Chavhan, (2022). "7E MODEL AN EFFECTIVE INSTRUCTIONAL," *Journal*, vol. 8, no. 1, doi: 10.36713/epra2013.
26. Joyce, G., Lilley, M., Barker, T., & Jefferies, A. (2019). Heuristic evaluation for mobile applications: extending a map of the literature. In *Advances in Usability, User Experience and Assistive Technology: Proceedings of the AHFE 2018 International Conferences on Usability & User Experience and Human Factors and Assistive Technology, Held on July 21–25, 2018, in Loews Sapphire Falls Resort at Universal Studios, Orlando, Florida, USA* 9 (pp. 15-26). Springer International Publishing.
27. Joyce, G., Lilley, M., Barker, T., & Jefferies, A. (2016). Mobile application usability: heuristic evaluation and evaluation of heuristics. In *Advances in Human Factors, Software, and Systems Engineering: Proceedings of the AHFE 2016 International Conference on Human Factors, Software, and Systems Engineering, July 27-31, 2016, Walt Disney World®, Florida, USA* (pp. 77-86). Springer International Publishing.