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Investigating Use of 5G and AR in School Education

Mimounah Ayed Alhujaili, Nouf Bader Aljabri, Raghad Majid Alharbi, and Sahar Abdullah Almutairi
College of Computer Science and Engineering, Taibah University, Madinah, Saudi Arabia

Abdul Ahad Siddiqi
Associate Professor, Department of Computer Science, College of Computer Science and Engineering, Taibah University, Madinah, Saudi Arabia
asadqi@taibahu.edu.sa

Abstract

Augmented Reality (AR) is a transformative technology, that seamlessly blending the virtual and physical worlds to enhance user experiences across various domains. This research paper provides a comprehensive review of the current landscape of AR with its different types, namely, marker-based and marker-less AR, exploring its diverse applications and delving into existing studies that highlight its impact on education. The paper further investigates the symbiotic relationship between AR and Fifth Generation (5G) technology, analyzing how the unprecedented speed, low latency, and increased connectivity offered by 5G networks can amplify the capabilities of AR applications.

Keywords: Augmented Reality, Virtual environments, Education, 5G, Marker.

1. Introduction

AR is an innovative technology that expands the user's physical world by adding virtual elements to the real world. The AR technique is a real interface between the real world and virtual data. It enables users to visualize a virtual object in its real environment and to recreated how it would act when in use [1].

Virtual reality (VR) has completely changed the way we see and interact with the digital world. It generates a virtual world that might resemble reality or be entirely unlike it. VR is a computer-generated simulation that enables interaction between users and a synthetic three- dimensional (3D) environment. Virtual reality has applications in entertainment, education, and business. 3D near-eye displays and pose tracking are two of the technologies used to give the user an immersive virtual environment. AR, VR, and mixed reality (MR) are all included under the general term extended reality (XR). The term "XR" describes a variety of augmented and virtual experiences that blend the real and virtual worlds to create captivating and immersive settings where users can engage with computer-generated content in real time. XR has been used in various fields, such as healthcare, education, entertainment, and even in everyday life. As XR advances, we might expect that it will fundamentally change our future and raise our standard of living by increasing immersion, engagement, and enrichment [2].

With the rapid change in technological progress and society in several sectors such as industry, education, health, etc. In this paper, we will discuss the development of education. AR has received attention in the field of education for its ability to enhance the educational process. Traditional tools have been replaced with modern tools because they combine fun and knowledge at the same time. Instead of education being one-way from sender to recipient, the student has become a participant in the educational process. Therefore, education has become more effective and easier because it helps students acquire and remember information easily. It also could enhance self- learning, and it is useful in simplifying complex information, especially in scientific subjects. It is used at all educational levels. So, teachers must now not only focus on developing learning skills, they must also develop their technology skills as well, they must support their explanation of lessons with AR [3].

2. Literature Review of AR

This section discusses the types of AR, namely marker-based and marker less AR. In addition, the use of 5G technologies in the field of AR. Also, various AR applications are categorized based on the subject being educated.

2.1 AR Types

2.1.1 Marker based AR:

Markers are images that can be detected by a camera and used as reference points to overlay virtual content onto the real world. A marker can be a QR code, a 2D bar code, or a bright color and meaningful pictures [4].

Marker Types: A good marker is one that can be unambiguously identified and detected by a computer vision system with robustness and reliability. The author in [5] proposes different types of makers.

- **Template Markers:** markers that are both black and white with a plain picture Template enclosed in a black border. Figure *1* shows an example of markers. Usually, detection systems match their segmented images with marker templates to determine who they are.

Figure 1: markers that are both black and white

- A detected marker is compared to each template by the application during the identification process, and the identity of the best match is determined.

  All template markers have an ID or name attached to them. A database is required by the system in order to link additional data to a template marker.

- **2D Barcode Markers:** They are made up of data cells that are black and white with the potential for a border or other landmarks. Usually, the system takes a sample of the pixel values from the computed center of each cell during the marker detection process, and then uses those values to resolve the cell values. 2D barcode markers can be divided into two categories: those that only define an identity (ID markers) and those that also contain additional data (data markers). Figure 2 shows an example of an ID marker on the left and a data marker on the right.

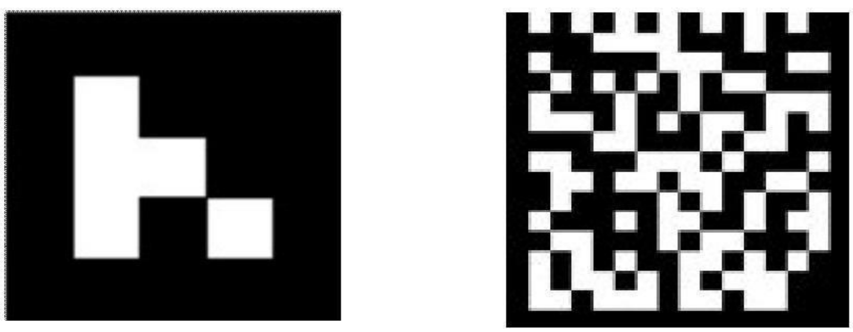

Figure 2: 2D Barcode Markers

- **Imperceptible Markers:** While visual markers are a useful tool for pose calculations, they may not be appropriate in all settings. People can use "nice-looking" image markers if "ugly" markers are the main source of the issue. The system can employ markers that are undetectable to the human eye but detectable by a machine if all patterns that are visible are undesirable. Using markers and detection equipment that operates on wavelengths other than

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visible light, such as those in the infrared range, is one option. Using markers that are too small for the human eye to distinguish is an additional option. These three options image markers, infrared markers, and miniature markers will be discussed in this section. Usually, a template or feature matching is used to detect image markers. The benefit of using implementations that identify images without frames is that augmented reality applications can function in their current surroundings without requiring alterations to the environment. For instance, an augmented reality application could improve a book without altering the book itself. AR apps could overlay additional 3D animation, visualization, and other features on top of an existing book's images.

Figure 3: Image marker

- **Image Markers:** Natural (color) images can be used as markers in a marker system. Although they are not required, image markers often include a frame or other landmarks to help with detection and pose estimation, as shown in Figure 3.

- **Infrared Markers:** The wavelength of infrared (IR) light is between 750 and 1mm. Since it is longer than the visible light spectrum (380–770 nm), the human eye cannot see it. But many cameras have near-infrared (near-IR) capability, which allows them to see light in areas close to the visible spectrum; other infrared cameras have a wider operating range. Additionally, there are specific filters that restrict the visible light to a particular infrared band. Retro-reflective material, an IR spotlight, or a self-illuminating marker can all be used in an IR marker system. It can also make markers using an infrared projector. If the system makes use of the near-infrared range, it can identify IR markers using a standard camera or a specialized infrared camera. Figure 4 Illustrates this type.

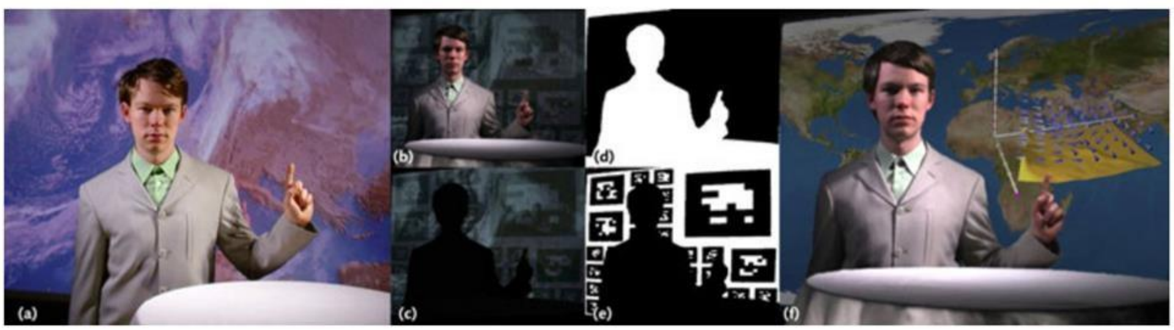

Figure 4: Infrared Markers

- **Miniature Markers:** It is a marker that is so small that the naked eye cannot see it. Figure 5 shows (on the left) marker appears to the human eye as a tiny dot, but when it is in out-of-focus mode, a camera can see its contents (on the right).

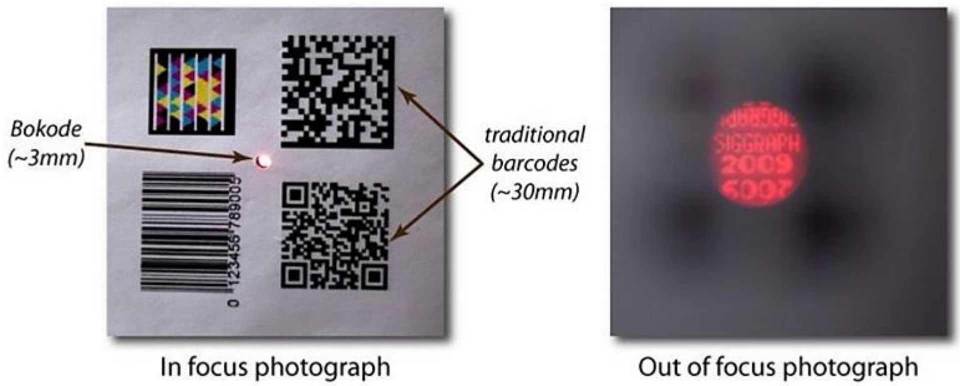

Figure 5: Miniature Markers

2.1.2 Marker less AR

Marker less AR is a software application that doesn’t need prior knowledge of the environment around the user to add virtual 3D content into a scene [6]. Digital data and real-time, real-world inputs recorded to a physical environment are combined in marker less AR. In order to register 3D visuals in the actual environment, the technology integrates software, audio, and video graphics with the cameras, accelerometer, gyroscope, haptic sensors, and location services of a smartphone or headset. Without any prior knowledge of the surroundings, marker less AR is able to identify objects or distinguishing features in a scene, such as walls or intersections. The visual effect that blends computer images with real-world pictures is frequently linked to technology. The earliest marker-less systems defined a device's position and orientation in space by interacting with accessible augmented reality resources through the use of hardware and location services. It is used widely in several fields such as children's education.

In 2021, Hatta et al. [7] emphasized the benefits of children learning English early in life, highlighting the relevance of their quick learning. It suggests using an AR application on an Android device to provide children with an interactive approach

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to learning English. The selected AR method is called marker-less augmented reality, which does away with the requirement for physical markers and provides a variety of scannable things, such as fruits and animals. The study's findings support the effective use of this AR approach, establishing it as a useful instrument for improving young learners' English language instruction.

2.1.3 Comparison of Marker based and Marker less AR

Table 1 depicts the comparison between Marker-based AR and Marker less AR.

	Marker-based AR	Marker less AR
Methods in Realizing AR	there are AR SDKs available algorithms can be used by developers can be automatically detect the marker and get the virtual element.	the developers have to develop their own algorithms and framework based on location and gyroscope technologies
Position accuracy	relatively low and depending on the accuracy of its location technology	high accuracy because the virtual element will be overlain on the marker just as it has been set in the development environment
Stability	comparatively less	comparatively greater
Hardware support	desktop and mobile supported	mobile supported

2.2 5G Technology and AR

The convergence of 5G technology and AR is poised to redefine the landscape of education. 5G's high-speed, low latency acts as a catalyst for the seamless integration of AR applications into educational settings enhances AR experiences and allows students to access and interact with immersive educational content in real-time. This combination has the potential to revolutionize education by empowering educators to transcend traditional teaching methods and offering students the opportunity to engage with dynamic, digitally augmented content .5G-enabled AR can make education more inclusive by providing tools for students with diverse learning needs. in addition to facilitating scientific research and virtually exploring complex scientific concepts or historical events. This paper [8] underscores the potential of 5G technologies within education, particularly with an emphasis on AR and VR applications. It emphasizes how 5G possesses the capability to meet the specific requirements of AR/VR applications in educational settings, offering enhanced performance. Additionally, the paper highlights the limitations of current network technologies in meeting these requirements, accentuating the imperative role of 5G in reshaping and enhancing educational contexts.

2.3 AR Applications in School Education

This section provides different applications of AR in the field of education with different subjects.

- **Mathematics**

In paper [9], the author aims to evaluate how AR impacts education and students' ability to retrieve information. Geometry Learning Assistant (GLA) aims to provide real-time examples to help them understand 3D geometry concepts. The applied polytechnic students were randomly divided into two groups: a control group (N=40), who were taught using Interactive Simulation (IS), and a participated group (N= 40) who were taught using the GLA application. After the learning process was completed, the students of both groups took a posttest to measure the students' benefit from this activity. To measure the students' memory recovery of information after the end of the activity, two evaluations were conducted. The first evaluation was two weeks after the end of the activity and the other was four weeks after the end of the activity.

Students were given scores based on performance ranging from 0 to 12. The results showed that GAL based on AR has a significant impact on students' memory and their ability to retain information, unlike IS.

- **Chemistry**

This study [10] focuses on the development of AR technology-based learning media for teaching molecular geometry in chemistry. The research involved stages of design and application development on the Android operating system, as well as a limited trial with chemistry students. The AR-based learning media was created using tools like Google SketchUp, Corel Draw X5, and Unity 3D, and it required registering markers through the Vuforia Developer site. The study employed a Design-Based Research approach to produce this AR learning tool, which successfully demonstrated its potential as an effective resource for teaching chemistry, with a testing score ranging from 70.83% to 92.50%, indicating its suitability for molecular geometry.

In this research [11], an experimental approach applied to evaluate the relation between variables and causation. Researchers were able to observe the effects of one independent variable on one or more dependent variables. in this research Includes one group pretest and post-test indicated with the following symbols: pretests (O1), treatments (X), and post-tests (O2). First, a sample was selected and divided into single-class research. First, the pretest was conducted, and then AR applications were used in the sample. After completing the teaching intervention, a post- test was given in the last, and the results were taken. Finally, this study demonstrates that AR media positively affects student education outcomes.

In this paper [12], have been collected 124 middle school students (ages 14–17) from six Mexican schools participated in this study's evaluation and survey. One student did not finish the tests; hence their results were not taken into account for this study's analysis. 58 responders were male, and 65 were female. It was a required learning exercise for every student. All parents or legal guardians of participants in the activity were asked to provide their informed consent before they could participate. The authors of this work developed an AR learning application called ReAQ, which is Marker-based. It was created for middle school students to help them practice and understand basic concepts of chemical reactions and bonds.

These results showed support for the initial hypotheses, which is that students learning outcomes improved after using the tool based on AR. Students experience immersion in learning science that includes AR- marker-based. Students with immersive profiles achieved better results than those with less immersive profiles. To summarize, the study established the benefits of an AR-based learning activity for students to master basic chemical concept addition to the students experience of immersive learning.

- **English Language**

Section 2.1 introduces an application for teaching the English language. The developed application described is an AR application designed to facilitate English language learning for children. The application is specifically created for Android-based devices and employs Marker less AR technology with the use of Vuforia AR tool, eliminating the need for physical markers. The primary objective of it is to make the English learning process funnier and more independent for children. The application features 10 scannable objects, including elephants, bears, tigers, camels, rhinos, bananas, apples, pears, oranges, and watermelons. When the application is used, the user can point the device's camera at a 2D image of these objects, which serves as the marker. Once the marker is detected, the application displays 3D objects or animations associated with the specific marker image. Users can interact with these 3D objects, and the application offers the capability to play sound, providing English translations of the scanned objects. The application's user interface (UI) is designed to be user-friendly, making it accessible for children. It includes features like a "Start" button, which initiates the AR experience, and a "Play Sound" button for accessing the English translations. The application aims to engage children in the language learning process and foster their interest in English through the use of interactive and visually appealing AR technology. The development and testing of this application have shown that it effectively captures children's interest and can be a valuable tool for early English language education. The paper mentions that the evaluation of the developed application was conducted through a questionnaire-based assessment, the developers asked if the application "makes learning fun" had the highest score for "strongly agree" at 35%. Also, if the application is "suitable for use when studying," had the highest percentage at 80%, which indicates positive responses.

- **Physics**

The study in [13] examined the effects of integrating AR with Problem-Based Learning (PBL) when teaching physics in a high school for juniors in Turkey. Using a quasi-experimental design, the study comprised 91 seventh-grade students in two experimental groups (one using AR-assisted PBL and the other using PBL alone) and a control group. Using marker-based AR technology, the study created FenAR software to improve PBL activities in the classroom. Students' physics

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learning outcomes were greatly improved by the incorporation of AR into PBL activities, with the AR-assisted PBL group demonstrating the greatest improvement. While the group using PBL alone did not show a significant change in attitudes, the AR- assisted PBL group also showed a significant positive shift in their attitudes toward physics subjects. Over time, AR technology helped students retain their understanding of physics concepts. The AR-assisted PBL group kept their scores when a delayed post-test was given three weeks after the first post-test, but the scores of the other groups significantly decreased. Students who participated in semi-structured interviews shared positive opinions about augmented reality apps. They discovered that AR improved their understanding and analysis of problem scenarios and was more engaging, lifelike, and effective for learning. The study concludes that incorporating AR into PBL activities improves learning outcomes, attitudes, and long-term retention of physics concepts. Students thought that AR apps were helpful and immersive for their educational experiences.

In this research [14] experimental approach applied to introductory physics laboratory course. The goal of this research is to at intensifying previous experimental physics lecture topics related to algebra. Two students formed two teams to conduct 10 experiments and analyze them for four weeks, with attendees spending 3 hours for each experiment. Before the experiment each student was given a text-based laboratory manual which gave an overview of the experimental setup and theoretical background that included tasks for the subsequent analysis. In all the experiments conducted, three stages were included: first, pre-preparation of the experiment independently. Second, During the class attendance period, they finish a series of experimental activities in a laboratory. Students set up tabletop experiments and carry out the measuring procedure after receiving the required laboratory equipment and the text-based handbook with schematic images. Third, they analyze their data mathematically after the experimental stage. Since the first and third steps were not controlled, an intervention occurred in the second step, and all variables were collected immediately before and during the conduction phase. AR technology is able to successfully convert simple laboratory environments from divided sources to unified presentational format with live data visualizations. However, superfluous processing was reduced throughout the performance.

- **Biology**

The authors in [11] developed an Android application of animal recognition using marker- based AR to support children's learning interest. According to their test, first the marker would not be detected if there was a distance of 1 to 7 cm between the marker and the camera. Second, if the distance was 8cm to 20 cm, then the marker would be detected clearly. Third, if the distance was 50 cm to 60 cm, then a small detectable marker. Finally, if the distance was 70 cm to 77 cm, the marker would not be detected. This marker-based AR app has been functioning smoothly on smartphones and includes information about three-dimensional objects. Applications developed by using Unity 3D and Vuforia Engine. Figure 6 illustrates the application interface.

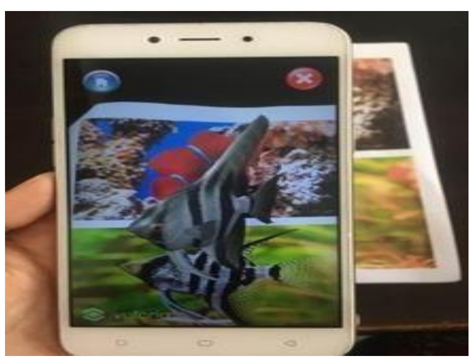

Figure 6: Animal recognition application

2.4 Summarization Table

Table 2 below shows the summarization table of various subjects along with information about types of AR, addition tools, AR devices, evaluation metrics, sample size and results.

Table 2: Summarization table

No.	Subject	Type	Additional Tools	AR devices used	Evaluation metric	Sample Size	Result
1	English	Marker less	Vuforia	Mobile	questionnaire-based assessment	Not menti-oned	80%
2	Sciences (Animal)	Marker based	Unity, Vuforia	Mobile	Grades and students' attention	91 seventh-grade students	The study showed an improvement in students' understanding and attention
3	Physics	Marker based	Unity, Vuforia	Not mentioned	Learning achievement test	Not menti-oned	86%
4	Chemistry	Marker based	Vuforia, Unity3D, Google SketchUp, Corel Draw X5	Mobile	questionnaire-based assessment	10 chemistry students at UIN Sunan Gunung Djati Bandung	92.50%

5	Mathematics	AR marker based application	Unity, Vuforia	Tabletop	80 polytechnic students	Quasi-experiment al pretest/ post	The results showed that there was a significant positive effect on memory retention when students experienced the AR-based GLA after 4 weeks of learning.
6	physics laboratory	AR based smart glass	Unity3D, Vuforia	Smart glass	74, Undergraduate Students	Quasi-experiment al pretest/ post	major laboratory environments were successfully converted from divided source to unified presentational format when AR technology was used and reducing the over processing throughout the performance
7	Science Class	Mobile Application	metaverse	Mobile	75 students grade 5 elementary school	Pretest and Posttest	The results shows that AR mobile affects positively on outcomes of student learning outcomes in science subjects
8	basic chemistry concepts	AR marker based application	ReAQ	Tablet	124, middle School Students	Pretest and Posttest	The results shows that AR It has a positive effect

3. Results and Discussion

At the end of our research, we observe that with the progress of development in educational technologies in school, the utilization of AR in school education has increased. We noticed that most subjects that use AR are scientific subjects like mathematics, chemistry, biology, and physics. In mathematics, the researchers found that using AR to explain 3D geometry concepts has a positive effect on the student's memory and their ability to retrain information. Also, Using Marker-based AR in biology to extend virtual 3D animals led to an increase in students' attention. Some researchers noticed that over time, AR technology helped students retain their understanding of physics concepts, so the AR-assisted PBL group kept their scores when a delayed post-test was given three weeks after the first post-test, but the scores of the other groups significantly decreased. In chemistry, all three studies that we summarize collectively highlighted the efficacy of AR- based learning media in enhancing educational outcomes, specifically in teaching chemistry concepts and improving students' understanding through immersive learning experiences. On the other hand, using AR in English learning applications for children provides a high level of satisfaction. Evaluation via a questionnaire revealed a strong agreement (35%) that the AR English learning app makes learning fun, and 80% agreed it is suitable for studying, demonstrating positive responses, affirming its effectiveness in engaging children and aiding early English education.

4. Conclusion

In conclusion, this research paper has looked into AR and how it's used in education. AR has two main types, marker-based and marker less. Both marker-based and marker less AR systems play crucial roles in integrating virtual content into the real world.

The choice between marker-based and marker less AR depends on the specific requirements of the application, the nature of the environment, and the desired user experience. Additionally, the integration of AR with 5G technology has unveiled a symbiotic relationship that amplifies the capabilities of both technologies. The unprecedented speed, low latency, and increased connectivity offered by 5G networks have the potential to propel AR applications to new heights. Furthermore, this paper provides some AR applications in the field of education. AR has been shown to have a successful impact on mathematics, chemistry, physics, biology, and English language education, and various studies have been discussed.

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