Augmented Reality in Education

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***Abstract*—The direction in introducing Augmented Reality (AR) in education has been perceived fairly well in the past few years. Aside from capturing the attention of students, survey has shown that learning by visualization is easier to grasp compare to another methodology. AR has broken the barrier of two dimensional image and turned it into a three dimensional model to assist students in learning materials. AR technologies enhance our perception and help us see, hear, and feel our environments in new and enriched ways. Although there are a lot of advantages comes from Augmented Reality, several challenges also comes along with it. This paper provides the definition of Augmented Reality by introducing the general concept of Augmented Reality and then describes how far of the advancement in education it has been implemented. The paper will also cover the advantages and the challenges of having Augmented Reality in education. FInally, the paper concludes with the current trend of Augmented Reality as well as the future of Augmented Reality in education.**

***Index Terms*—Augmented Reality, Education, Technologies, Applications, Limitations**

I. INTRODUCTION

Augmented Reality is known as imaginative technology of interaction between people and holographic elements. Augmented Reality (AR) is a technology that blurs the line between a live view of the physical/real world, and computer-generated world to create a mixed reality. Moreover, AR enhances our perception of the reality by interacting and adjusting human surrounding environment. Thus, AR enhances what we hear, see, smell and feel, adding sounds, graphics, smell and even haptic feedback to the world as it exists. Special devices such as smartphone and tablets allow the combination of digital data with the user's environment in real time. These devices are very accessible and open the opportunity for educational institutions to develop classes with more interactive content for the students. For instance, the high resolution that AR allows in the design of its graphics will allow the students to interact not only what is ahead of them, but around them like a peripheral vision; this will facilitate the learning process in their educational career [1].

Azuma (1997) stated that an "AR system combines real and virtual objects in a real environment; registers (aligns) real and virtual objects with each other; and runs interactively, in three dimensions, and in real time [2, 3]." AR is both interactive and registered in 3D as well as combines real and virtual objects [4]. AR aims at simplifying the user's life by bringing virtual information not only to his immediate surroundings, but also to any indirect view of the real-world environment, such as live-video stream. Thus, AR enhances the user's perception of an interaction with the real world.

II. CATEGORIES

Different applications of augmented reality can be found in the world of technology, each of them display unique elements, features and components. The following are the different kinds of Augmented Reality applications:

A. Marker Based Augmented Reality

This amazing technology it is also called Image Recognition. It takes the device's camera and a visual marker (QR / 2D) from the real world to create a magnificent augmented reality result. Also, this outstanding technology easily recognize the patterns from the visual marker without requiring a lot of processing power to read. In addition, the location and alignment of the camera is calculated by the application and replace the visual marker with the specific content. Below, there is a user choosing the perfect rim using Marker Based AR.

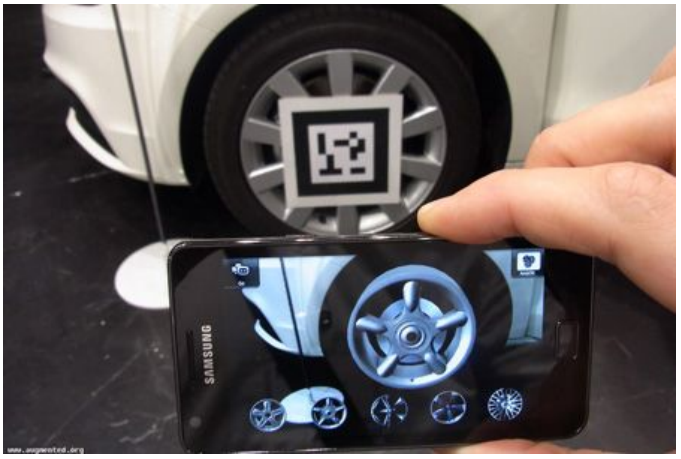

Figure 1. Marker Based AR

B. Markerless Augmented Reality

This is one of the most important application used in the augmented reality world. This app does not require a visual marker to display its' features. It only needs the location-based GPS [5]. This wonderful technology uses a GPS from the smartphones and provide data based on your location. It is normally used for mapping directions and finding close businesses. Markerless AR also allows a user transform his real environment into a game world, so users can play anywhere..

C. Projection Based AR

This technology is based on the idea of projecting images onto real world; it allows the touch interface between the light and the human interaction [1]; it is accomplished by distinguishing between an expected projection (artificial light) and the altered projection (human interaction). Below, there is an example of the Human-computer interaction using AR.

Figure 2. AR Human Interaction

D. Superimposition Based Augmented Reality

This technology changes the augmented view on the device by replacing an object from the real world with a similar holographic element. This object recognition is a very important aspect because the app can only change the original object with an augmented one if it defines what the object is.

III. HOW DO AR DEVICES WORK?

Augmented realities can be shown on different ways such as monitors, handheld devices, glasses, smartphones, tablets, google glass, and other head-up displays. Adding on these devices allows the user to interact easily with the AR because it can be place directly onto your face and fit in your hands. As technology advances, augmented reality devices will progressively need less hardware and apply this technology to virtual retinal displays and lenses.

The main components of the Augmented Reality devices are sensors/cameras, projection, processing, and reflection.

- **Sensors and Cameras**
  Sensors and cameras are located outside of the devices and its function is to obtain the physical information from the real world and then project a digital model to that specific surrounding area.

- **Projection**
  This component refers to the actual projection made by the device's sensor/camera to the actual world. The projector can basically change any external surface into an interactive environment.

- **Processing**
  Nowadays, all the devices are tiny supercomputer composed by technology such as RAM, Bluetooth/Wifi, GPS microchip, CPU, a GPU, flash memory, etc. These component facilitate the processing task of the device to create augmented reality projected by the sensors and cameras.

- **Reflection**
  Mirrors are an important factor to the reflection component because they allow assistance with image alignment to the eyes of the users. Some devices uses small curved mirrors, others double-sided mirrors. The idea with the mirrors is to create an optical projection to generate holograms to the user.

Augmented Reality can be controlled

Devices that handle augmented reality can be controlled in two different way, by voice command or touch a pad. Voice command work with a small microphone inside the device that capture the voice of the user and then a microprocessor will read the commands. The touch pad works when the user generates a pressure, tap, or swipe to a specific spot of the screen.

IV. APPLICATIONS

Although AR has been introduced as early as 1990s, the implementation in education is still in the beginning phase. Some of the education areas have shown significant improvement for students to understand the concepts, for example: science, medical, and engineering.

A. BIOLOGICAL SCIENCE

One of the most significant benefit of using AR in education is in Biology area. With the introduction of AR concept, it gives the ability to produce a complex molecular model into a auto fabrication 3D computer model. By doing so, it gives the illusion of a real molecular model to assist user in understanding the layers. With the ability to provide the realism of molecules, it helps scientists, as well as students, in breaking down the molecules of a sickness, for example the HIV Protease. Aside from molecules, it also provides the support of displaying the realism of enzymes, for example: Superoxide Dismutase (SOD), and Ribosome [6].

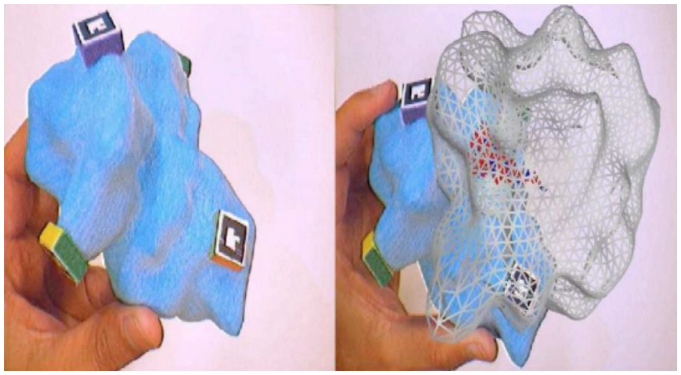

Figure 3. Ribosome with and without AR

B. CHEMISTRY

The foundation of chemistry studies is understanding the materials structures of a component. Often times, these structures are getting more complicated as the studies advanced, especially when dealing with Organic and Inorganic Chemistry. By introducing AR to chemistry, it gives the opportunity for the students to inspect a set of material structures without having to rely on imagination or computer 2D graphics.

Aside from modeling purposes, students also get a hand-on experience to restructure and manipulate the materials independently. This possibility will not only educate the students in the chemistry field but also as a brain exercise in 3D analysis and perception skills [7]. Below are some examples of material structures displayed through AR technologies:

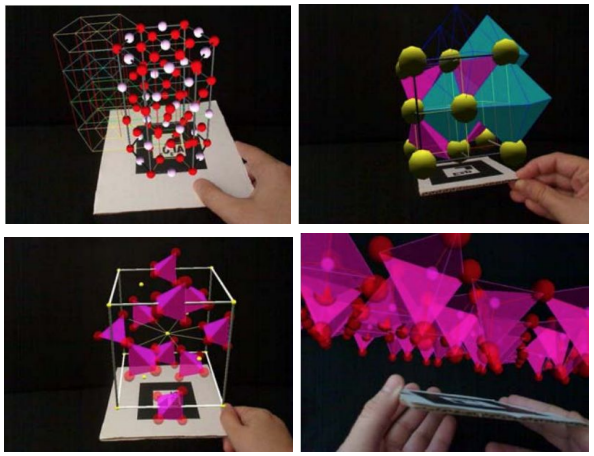

Figure 4. Materials Structures Visualization using AR

C. MEDICAL TRAINING

With the current state of art, the medical training has been heavily studied and integrated with Google Glass and Hololens [8]. Both of these are used to assist patients in need and also to educate people with no medical experience and people that are new in medical field.

One concrete example of medical education with AR is the response from the mankini that behaves differently depending on the treatment given. Though in reality it might not turn out to be precisely like the stimulation, it gives an idea for the students to see common responses from the patients. According to the survey performed by Zhu *et al.*, training that utilize the AR technologies decrease the amount of practice time while yielding more success rates [8].

Another benefit of using AR in medical field is the live feedback that the doctors received. By integrating AR, doctors can see the response directly while assisting the patient virtually. With the popularity of integrating medical providers with AR, it shows a promising development that will grow rapidly in the next few years [8].

V. ADVANTAGES AND DISADVANTAGES

With education constantly evolving, technology is also evolving in such a way that facilitates the way education is accessed, and improved with the recent use of Augmented Reality. Although the use of AR has positively contributed to the grow of education, there are also limitations that come by introducing AR in education.

A. ADVANTAGES

The main advantages of AR in education include, learning gains, motivation, interaction and collaboration. According to Baca *et al.*, studies have shown that AR has demonstrated its extreme usefulness for increasing the student motivation in the learning process[9]. Through AR's motivating and engaging elements, it offers students a driving factor that keeps them fully engaged in learning, leading towards an improvement in learning performance. AR provides an environment that combines aspects of the real world with virtual objects. These virtual objects may be manipulated by students in any way they please causing the environment to exhibit high levels of intuitive interaction. High levels of interaction can directly lead to an improvement in learning performance and content understanding.

There are many different ways for people to be educated and trained with regard to specific information and skills they need. Different methods such as classroom lectures with textbooks, computers, devices, and other electronic appliances are traditionally used around the world. However, in a rapidly changing society where there is a great deal of available information and knowledge, adopting and applying information at the right time and right place is needed to maintain efficiency in both school and business settings. AR is one technology that dramatically shifts the location and timing of education and training.

AR has the potential to change and boost the traditional education system, enhance contemporary educational environments, and create enriched learning opportunities for students around the world. Nowadays, AR is used in Education as a technological tool to enrich regular curriculum

integrating interactive technology and mobile applications in online and distance learning environments for students. AR transforms traditional educational reading materials, such as textbooks or flashcards, into interactive multimedia format materials using multimedia (audio/video), text, and graphics [10]. In fact, Kuruback stated that the use of AR in Education allows to develop students "higher levels of independent thinking, creativity and critical analysis."

Likewise Klopfer (2008) affirmed that new technologies as AR engages students to solve meaningful and realistic problems. As a result, students and teacher in different places are able to connect with peers with the same interests by sharing a common virtual learning environment [11].

AR provides "rich contextual customized learning environments and contents [12]" to students from an extensive variety of local information obtained previously from different sources. Wang (2012) stated that acquisition of knowledge through educational activities is diverse and depends on the learning processes of each student; thus, AR applied to the curriculum strengths the acquisition of knowledge and provides an active interaction between the student, the reality and virtual environments which combined together foster meaningful learning [13].

B. DISADVANTAGES

Although the use of AR in education provides multiple benefits, there are also limitations that AR technology face. A disadvantage AR faces in education is *attention tunnelling*. Students are reportedly experiencing a higher demand of attention when using AR systems[14]. Students are required to pay more attention to what they read and do because of the high level interaction with the environment. Therefore, their cognitive load is much higher with extraneous load[15]. At a higher cognitive load students tends to ignore or miss important part of the experience which will makes them feel like they are unable to perform certain tasks properly.

With the complexity of AR technology evolving with education, several studies find that AR systems may exhibit *usability difficulties*. Some students report AR systems as more difficult to use than the physical or desktop-based alternatives[16]. Various complications may arise while using an AR system whether is be from the actual system itself or user error. Additionally, those reports have indicated that various aspects of the AR system's functionality may be difficult for some students to interact with due to different collaboration issues.

AR enables students to fully immerse into an environment that combines the real world with virtual objects, giving them a sense of isolation. This results in *ineffective classroom integration* within the classroom experience. A report, provided by Kerawalla *et al.*, indicates that children were more engaged in educational activities involving role-playing and exploration in a non-AR environment, as opposed to an AR experience, where the teacher took over the discussion and limited student engagement[17]. AR easily causes this limitation as students are provided and exposed to their *own* environment, which directly leads to minimal classroom interaction.

Lastly, every student has different levels of educational comprehension. The effectiveness in the way education gets delivered to students is subjective, as each person learns best in their own, different ways. Some reports have shown that high-achieving students do not receive any learning gain through the AR experience, whereas low- and average-achiever students did [18]. In addition, students who were low-ability readers also did not learn from parts of the AR experience. Effective learning is subjective to the student, therefore some students may find that using AR in education is much more effective than other students perceive. With that, AR may be a difficult solution to implement in a classroom setting if the students all have very different comprehension levels.

VI. CHALLENGES

Just like any other new technologies, implementation of AR in education system brings challenges to the users (students), teachers, and technology aspects.

STUDENTS

Since the introduction of AR in education filed, several challenges faced by the students are listed below:

- AR is difficult to introduce to students for the first time [19]
- AR distracts students' attention [20]
- Frustration due to localization error [21]

A. TEACHERS

Just like the students, the challenges also faced by the teachers. Below are some of the common challenges faced by the teachers:

- Inadequate teacher ability to use the technology [22]
- The limitation that hinders large group teaching
- Lack of support to tailor the context according to the teacher's teaching style

B. TECHNOLOGY ASPECTS

Though both of the parties experienced some challenges in regards of using AR in education, some of the challenges also encountered by the architects or the designers due to technology limitation. Below are some challenges encountered:

- Large file size limits the sharing of content [23]
- Technical problems due to network instability or incompatible hardware tools
- Time consuming in designing a certain AR for specific subject or specific niche

VII. TECHNOLOGIES USED

There are different variety of technologies that can be used for AR. In any AR related field; including education, technology plays an important role. AR can be accessed from different technologies, for example PCs, Mobile Phones, or one of the Virtual Reality specific devices. According to the survey conducted by MuratAkçayıra and Gökçe Akçayır, the most commonly preferred technology is Mobile Devices as shown in the figure below [24]:

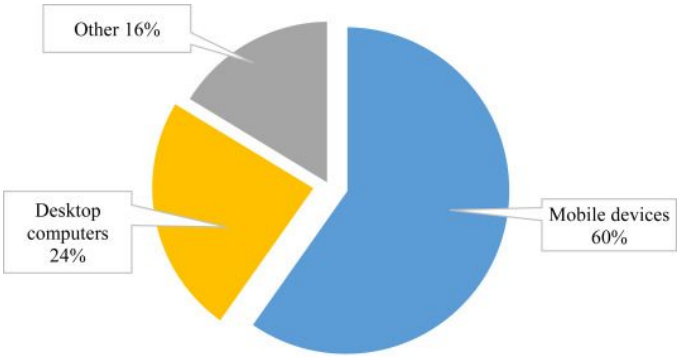

Figure 2: Distribution of AR technologies used

The reasons behind the preferable technology of mobile devices in contrast to desktop computers are compiled in the table below:

	Mobile Device	Desktop Computer
Cost	Lower	Higher
Easiness	Easy to use	Need certain setup
Portability	Portable	Not portable due to hardware limitation
Operability	Independent operability	Depend on power source and other components
Location Based	Enable	Disable

Table 1: Comparison between Mobile Device and Desktop Computer

VIII. EFFECTIVENESS

Augmented Reality integrated in educational uses has been noted to be most effective via an interactively collaborative setting. Based on a study by Espiga and Blanca, they conducted a survey to compare the effectiveness of AR-based application against the web-based application mainly for the goal. At the same time, the survey also generate a result of students' level of enjoyment. Both applications equally intended to provide the same information and workflow capabilities. One result indicated that students who participated in the AR-based application experienced a more positive mood following the learning activity than the students who used the web-based application[25]. This provides evidence that using AR can keep students engaged and motivated to continue the curriculum. If a student is either frustrated or bored after a learning activity, it is a good implication that they will not be motivated to continue the learning activity. AR in education provides an effective way of keeping participants engaged and motivated in the learning exercises.

The educational experience offered by Augmented Reality is different for a number of reasons as Mark Billinghurst (2002) stated [26]:

- Support of seamless interaction between real and virtual environments.
- The use of a tangible interface metaphor for object manipulation.
- The ability to transition smoothly between reality and virtuality

Additionally, the study further supports that AR is an effect alternative to education integration by acknowledging that it helps students to concentrate on the tasks in the learning activity more attentively. Espiga *et al.* states that AR-based education is adequately effective at increasing concentration among students due to the manipulation features of AR in the learning context which promote students' concentration [25]. Furthermore, students who participated in the AR-base application had a better sense of control and clearer direct feed-back than the students who did not use the AR-base application, which can be an effective benefit for the recall of information.

IX. CONCLUSION

Augmented Reality is an interactive system which integrates virtual objects into the real world users can experience and interact with. AR has allotted an alternative to the way education is delivered. In this report we have discussed the various educational applications to which AR may be applied to such as, biological science, medical training, and chemistry. AR-based education provides an effective way of motivating and increasing the concentration levels of students, which may result in better performance in learning activities. Although this alternative provides many benefits and advantages in an educational environment, it also faces limitations and challenges that may hinder the experience such as attention tunnelling and usability difficulty.

As information technologies transform, teachers have always looked to adopt new technologies into their classroom to strengthen student learning experience. AR is one the growing technologies that have not only great acceptation by teacher

but also it is a great pedagogical potential in improving the quality of teaching and learning activity merging virtual and real worlds together given birth to new educational possibilities. Augmented reality makes the impossible possible and its potential in education is just beginning.

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