



## The Effects of Using an Anatomy 4D Augmented Reality Application on Student Performance in Biology in Saudi Arabia

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**ABSTRACT** The purpose of the study is to examine the application of augmented reality (AR) as an interactive and exciting means of creating real-time and real-world experiences in teaching biology lessons. The primary objective of this study was to investigate the impacts of the Anatomy 4D app and (AR) software on student performance in biology. A quasi-survey was used to assess the impact of using Anatomy 4D, an AR mobile application, to improve student performance in biology as well as trigger their interest to pursue medical-related university courses in the future. Sixty students were randomly (30 boys and 30 girls) selected from secondary schools in the Northern Borders region of Saudi Arabia. The outcome of the study revealed that Anatomy 4D was significantly related to higher motivation, student achievement, and the desire to pursue biology courses in the future. The study recommends for educational stakeholders to implement beneficial application to enhance student participation, learning, and performance.

### INTRODUCTION

Augmented Reality (AR) is an interactive and exciting means of creating real-time and real world experiences. The study by Mertoglu and Kurt (2017) reported that even though several different definitions of the technology exist, it is commonly accepted that AR uses applications to project real-time images. Gerardo and Marisol (2018) define augmented reality as a technology that involves 'augmenting' objects or materials existing in the real-world across several sensory modalities (olfactory, visual, somatosensory, haptic, and auditory) using computer-perceptual information. Sural (2017) adds that it is a technology that overlays or superimposes computer-created images on perceptions or views of people of the true or real-world, which leads to a composite/merged insight. The overlaid or superimposed information can either be destructive (masks or camouflages the real environment) or constructive (adds to the natural environment).

Augmented reality technology has been influential in a number of fields in recent years. In particular, Perez-Lopez and Control (2013) believe that its entry into the education sector significantly improved the learning experience especially for students. AR has significantly changed experimental learning experiences classroom settings by being able to project or superimpose

digital items onto real-world surfaces like holograms. According to Khan et al. (2019), several augmented AR applications can potentially improve learning activities better than traditional and cumbersome textbooks and/or whiteboards. These new applications such as Sky Map and Anatomy 3D can allow learners to animate and actively interact with difficult lessons using their devices.

According to Alshumaimeri (2011), academic performance in Saudi Arabia and other Arab nations is usually low versus their western counterparts because of the persistent use of traditional reading and learning techniques. Even though AR is a new idea in the education sector in Saudi Arabia, recent successes in other countries have opened doors for its potential widespread applications in coming years - not only in the country but other parts of the world. Similar to advertisements and cinematography where AR has successfully given real objects (usually captured on video or camera leading to computer-generated or virtual outlook), augmented reality can potentially change the learning experience in education. Trelease's (2014) study reports that with new, high-tech software, it is increasingly easier to overlay reality with an imagined world and offer a wide range of possibilities for tutors to improve the learning experience. Introducing augmented education in

Saudi Arabia can significantly boost the teaching experience in a number of ways (Hou et al. 2013). It can motivate and inspire learning experience in the traditionally monotonous classroom environments. According to Khan et al. (2019), augmented reality can transform each session into a new exciting experience for students and can potentially keep them inspired, excited, and encouraged. Each lesson can turn into a new-fangled ride or expedition for learners especially in subject areas previously considered difficult to understand such as mathematics and sciences (Hou et al. 2013). For example, the use of Anatomy 4D can improve student memory of the biological parts of the body including the heart, blood vessels, lungs, and many others. Besides, augmented reality can create more participatory and interactive learning environments in contrast to the dull and teacher-centered education currently utilized. Based on Hou et al. (2013) argument, most importantly, AR offers modern and high-tech ways of content presentation that can enhance student collaboration and deepen student-teacher engagement. Notably, higher learning involvement can potentially improve satisfaction among students and foster deep learning, which increases the chances of learners memorizing concepts (Alfanita2014). With improved long-term memory, students will likely excel not only in examinations but also in the field of practice. Finally, more motivated and engaged learners are likely to learn and grasp ideas faster compared to discouraged and uninterested students because their concentration and effort are primarily focused on acquiring knowledge. Based on Alfanita's (2014) findings, augmented technology can maintain this concentration by making lessons and learning materials more attractive, engaging, and attention-grabbing. Furthermore, AR can enhance education in classrooms by providing learners with a more practical approach to knowledge acquisition. The old-fashioned style of teaching has failed to improve learning in sciences and mathematics- these are some of the most technical subjects in Saudi Arabia. This might be because of its dependence on the theoretical model only. The inclusion of AR technology can break this norm by introducing a more hands-on approach that is critical to memorize concepts. In particular, the AR technology

can generate real-time simulations that learners can use to build their practical knowledge (Hou et al. 2013). Anatomy 4D is a software application that uses the Android operating system. It uses AR technology and features to allow learners to freely interact with the anatomical features of the human body. The application requires learners to first draw a blueprint image (4D) of the heart or the human body from the software's library. The application then utilizes the camera mounted on the device (tablet or phone) to create a three-dimensional image that is virtually (Real Educational Pasture n.d.). Therefore, this work is critical to creating awareness among stakeholders of the need to create a more interactive, exciting, approachable, and entertaining learning environment. Augmented reality presents this opportunity by allowing students to interact with computer-generated images in real-time. This is more likely to improve their memory and performance in examinations and later in practical fields. Thus, these results suggest that embracing Anatomy 4D AR technology is a necessity to boost student performance in biology.

### Research Questions

This research aims to answer the following questions:

1. What are the primary benefits of AR in education?
2. What are the effects of Anatomy 4D app on biology student learning experience and performance?
3. Can the use of the Anatomy 4D app improve student performance and memory in biology?
4. What is the impact of Anatomy 4D AR technology on student interest to pursue future biology-related medical courses?

### Literature Review

#### AR Technology

According to Gerardo and Marisol (2018), AR is a modern technology that allows the modification of real-life events using computer-generated applications that include the addition of visual or sound content. Mobile applications

are the most recent and common application of. This technology overlays or superimposes computer-created images on perceptions or views of people of the true or real world; hence, it gives a composite/merged insight. The overlaid or superimposed information can either be destructive (masks or camouflages the real environment) or constructive (adds to the natural environment).

According to Perez-Lopez and Contero (2013), the concept of augmented reality is currently widespread and applicable in all sectors—perhaps because of the increased innovation and need to improve human interaction with the environment. Perez-Lopez and Contero argue that AR technology has been prominent and influential in different sectors years especially in entertainment advertisement whereby companies are designing modern ways to bring images and videos into real-time scenarios. They further suggest that AG is presently making a grand entry into the education sector with the potential to create a more interactive experience between students and teachers. The two researchers argue that the ability of AR to superimpose digitally generated videos and images onto real-time and observable platforms has considerably transformed experimental learning experiences in classroom settings.

Sirakaya (2018) added that modern augmented AR applications—especially applications specifically structured for training—are currently changing student learning experiences in a positive way. This is because of the ability of these techniques to introduce learning activities that are more interactive and better than the conventional and cumbersome textbooks or whiteboard teaching tools. These modern software tools such as Sky Map and Anatomy 3D can help students understand difficult concepts faster and more easily; these can often take several weeks or months to master with conventional learning. To demonstrate the impact and influence of AR technology on student self-efficacy and performance, Sirakaya (2018) developed a Hardware AR application to test the ability of IT students to remember computer hardware assembly procedures. Hardware AR is a software program that gives information about the features and characteristics of computer hardware ports, assembly, and other components. Later, Sirakaya used

a quasi-experiment model to test the ability of 46 computer students pursuing a degree course in computer science to assemble computer components. Each participant was given a questionnaire to test their motherboard assembly skills and efficacy and computer course achievement. The researcher also used unstructured observation forms to collect all necessary data.

For comparison, the study required the control group to learn all the motherboard assembly skills theoretically using written manuals and textbooks. The experimental or treatment group used the developed hardware (a practical approach) to master the motherboard assembly skills. The outcome of the survey revealed that the use of augmented reality technology was directly connected with student achievement—motherboard assembly abilities and skills. Learners who used AR technology completed their task in 20 percent less times than those who used paper manuals. They also committed 50 percent fewer errors. Hsao (2010) also designed a similar experimental survey to determine the influence of AR on access and learning efficacy among students. Here, the researcher used a modern idea of designing CARLS (Chemistry Augmented Reality Learning System) by incorporating physical activity into the existing education curriculum. The three physical exercises introduced into teaching include flexibility fitness, muscle strength, and aerobic fitness. Hsao discovered that learners who incorporated all the three physical exercises into their CARLS program had improved performance versus those who only applied their old-fashioned Key-Mouse technique (KMCAI). Students who used CARLS demonstrated a more positive training attitude towards science-related subjects than those that stuck to their traditional KMCAI model.

Similar studies have also indicated a correlation between augmented reality technologies and improved learning abilities among students in other parts of the world. For example, Wojciechowski and Cellary (2013) discovered that the use of AR technology draws student interest and attention during lessons and improves motivation. Furthermore, augmented reality offers an opportunity for tutors to give student-focused training (Wu et al. 2013). Furthermore, researchers argue that AR is critical to motivating students to pursue science-based

subjects. To prove the aptitude of augmented reality to increase learner's interest in Science, Technology, Engineering, and Mathematics (STEM), Hsu et al. (2017) recruited 32 high school students from renowned senior high school in Taipei City, Japan. Twenty-six female and twenty-six male learners were selected for the study, and a majority of them hailed from middle and upper-class families. The learners were first grouped into two parts using a simulator-loaded tablet. Each group was required to complete two augmented reality lessons: cardiac catheterization and laparoscopic surgery. After finishing all the AR lessons, students were required to complete survey to gauge their sentiments, perceptions, and feelings towards the AR technology simulators and experiences. The researchers intended to use the outcome of the experiment to design new training equipment for teachers based on the suggested model of the design-enact improve model that is often applied when science-based technologies are implemented in education.

Hsu et al. (2017) discovered that the use of AR in both cardiac catheterization and laparoscopic surgery increased student interest in all STEM subjects. The perceptions of learners stood at an overall mean of 4.1. Motivation and engagement of students were also extremely high with mean attainment of 4.3. Hsu et al. also revealed that the AR lessons invoked some future interest among learners to pursue medical courses in college. For example, 12 students indicated a willingness to pursue STEM-related professions in university. This study establishes lessons specifically tailored to students with less interest in sciences. Saudi Arabia and other less developed Gulf countries can embrace this new technology to inspire high school learners to pursue STEM courses, which are key economic drivers. Thus, Saudi students can compete in the highly competitive and high-tech world.

### ***The Learning Approaches in Saudi Arabia***

Even though Saudi Arabia is slightly above other Gulf nations including the United Arab Emirates in terms of improving learning approaches, other technocrats still feel that the country performs poorly in science-based subjects-especially those areas require the use of English as second Language. Wiseman et al. (2008) underscore the need to incorporate mod-

ern learning technologies such as AR to improve the education interest of students in the region particularly IT courses. In their paper presented to the IEA body for international research, Wiseman et al. exposed how a lack of resources including modern technology is hurting the learning environment in Saudi Arabia.

Their study was mainly aimed at establishing the influence of resource indicators and socioeconomic status in learning institutions in the country. This indicated that national averages in science and math achievement were low versus other nations both globally and regionally in the 2003 TIMSS (Trends in International Mathematics and Science Study). TIMSS is an international organization that majors in the large-scale evaluation of science and mathematics to inform educational practice and policy in these two subject areas. The three experts requested that educational policymakers in Saudi Arabia identify and implement clear educational reforms and consider the importance of mathematics and science in encouraging socioeconomic reforms. Despite these persistent calls for reforms in Saudi Arabia, there are still gaps in research to establish the actual benefit of AR in enhancing educational experiences among students in the Gulf. Several studies have been conducted in neighboring countries like Kuwait on the potential of AR to improve student performance, but Saudi Arabia has yet to assess the effects of this modern technology. For example, Safar et al. (2017) discovered that AR mobile applications had significant effect on English learning abilities especially the English alphabet letters among Kuwaiti kindergarteners.

These regional and global developments were critical to shaping this particular study. Their search mainly targeted Saudi Arabia as a potential hub for augmented reality in teaching. The researcher projected that using Anatomy 4D application to teach biology students can significantly improve their performance and memorization of the concepts and also create a new interest to pursue medical courses in the university.

## **METHODOLOGY**

### **Participants**

This quasi-based survey assessed the impact of using Anatomy 4D, an AR mobile appli-

cation, to improve student performance in biology as well as trigger their interest to pursue medical-related course at the university level. The quasi-based survey design was selected since it allows comparison between Anatomy 4D and AR mobile application to identify how they improve student performance in biology subject. Sixty students (30 boys and 30 girls) were randomly selected from secondary schools in the Northern Borders region of Saudi Arabia. The performance of students was assessed by selecting a total of 20 students from each of the three levels (year one, year two and year three). The inclusion criteria include a score below 50 in biology in the previous examination, an indication that students are less motivated and less interested in the subject, and the learners must fall within one of the three-year learning programs offered by the school's curriculum. However, to ensure that the research addresses the main subject, other units and strands were excluded from the study.

### Study Design and Data Collection

This study was classified into two main parts: section one (administering lessons to the participants) and section two (data collection using questionnaires on the performance and perception of students about biology). However, the researcher administered two learning sessions to effectively determine the effects of Anatomy 4D in learning and memorizing anatomical body structures including the heart: the experimental and the control. For the experimental session, all 60 students were given a 30-minute lecture using the help of Anatomy 4D application to guide their study. In particular, each student was given a tablet containing the Anatomy 4D application to view all the structures and func-

tions of the heart. The students were split into three groups of 20 students each based on their year of study. For the control session, the teacher was supposed to teach the same group of students for 30 minutes using traditional chalkboard and textbooks without AR technology.

The second part of the experiment involved giving students open-ended questionnaires: Each was required to state their opinion on whether they would pursue a biology-related course at university in the future. A simple assessment test about the functions and parts of the heart was issued to the students. The students were required to name the part and its function and they were ranked on their outcome. Notably, both the first and the second parts of the experiment were administered to the experimental and control groups. An example of the questionnaire that the researcher used to collect data (see Table 1).

## FINDINGS

The findings of the study were divided into three main parts: the performance, motivational levels, and pursuit of higher education biology courses in the future.

### Performance

Tables 2 and 3 indicate that a majority of students in each particular year of study scored above 50 percent when Anatomy 4D was used as a part of the lesson compared to the traditional teaching techniques using a blackboard and textbooks. For example, for year one, 16 individuals scored above 50 when AR was used versus only 8 when the technology was absent. Similarly, on average, 43 students scored above 50 percent for the AR technology with only 17 scor-

**Table 1: An example of the questionnaire that the researcher used to collect data**

<i>Parameter</i>	<i>Outcome</i>
<i>Student Name</i>	
<i>Year Study</i>	<i>(Year 1, Year 2, or Year 3)</i>
Marks scored (percentage) with the Anatomy 4D AR technology in place	(percentage)
Marks scored using textbooks and chalkboard teaching techniques	(percentage)
Student motivation score	(1-highly motivated, 2-averagely motivated, and 3-less motivated) for both classes)
Student's view on future plans to pursue biology-related courses	(Yes/No)



ings below. Contrarily, only 18 managed 50 percent and above when the chalkboard and textbooks were used.

### Motivational Levels

Tables 4 and 5 show that students were more motivated to participate in biology lessons when

**Table 2: The general performance of students when Anatomy 4D was used as well as chalkboard and textbooks**

<i>Year of study</i>	<i>Marks Scored (percentage)</i>	<i>Anatomy D</i>	<i>Chalkboard and textbooks</i>
1	Below 20	0	2
	20-50	4	10
	50-80	15	8
	Above 80	1	0
2	Below 20	0	5
	20-50	10	11
	50-80	5	4
	Above 80	5	0
3	Below 20	1	4
	20-50	2	8
	50-80	10	6
	Above 80	7	2

**Table 3: The total marks scored by students in all classes in the two sessions**

<i>Marks scored (percentage)</i>	<i>Anatomy 4D</i>	<i>Chalkboard and textbooks</i>
Below 20	1	11
20-50	16	29
50-80	30	18
Above 80	13	2

**Table 5: The total number and ages of students for each motivational level for the two groups**

<i>Motivation levels</i>	<i>Anatomy 4D (student number)</i>	<i>Percentage</i>	<i>Chalkboard and textbooks (student number)</i>	<i>Percentage</i>
Highly motivated	48	80	14	23
Averagely-motivated	11	18	36	60
Less motivated	1	2	10	17

**Table 6: Interest of students in taking biology-related courses**

<i>Year of study</i>	<i>Anatomy 4D (number of students)</i>		<i>Chalkboard and textbooks (number of students)</i>	
	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>
Year 1	15	5	10	10
Year 2	16	4	7	13
Year 3	12	8	5	15

**Table 4: The student motivation score in each study year**

<i>Year of study</i>	<i>Motivation levels</i>	<i>Anatomy 4D (number of students)</i>	<i>Chalkboard and textbooks (number of students)</i>
1	Highly motivated	16	4
	Averagely motivated	4	14
	Less motivated	0	2
2	Highly motivated	14	3
	Averagely motivated	5	12
	Less motivated	1	5
3	Highly motivated	18	7
	Averagely motivated	2	10
	Less motivated	0	3

the AR technology was introduced: 80 percent of the students were highly motivated, 18 percent had the average motivation, and 2 percent was less motivated. Very few students were interested in learning in the control experiments using only chalkboard and textbooks. Only 23 percent was highly motivated.

### The Pursuit of Biology-Related Higher Education in Future

Table 6 presents the number of students willing to pursue a biology-related course in the future after receiving a lecture using Anatomy 4D AR technology. The fourth and fifth column represents the number of students willing to pursue a biology-related course in the future after receiving a lecture using books and chalkboard (without AR technology). Similar to motivation-

al levels and performance, more students showed a willingness to pursue a course in biology in their future college education when AR technology was used than when the traditional chalkboard and textbooks were used. For example, of the year three learners, 12 agreed to take a course, and 8 disagreed when technology was used. On the other hand, only 5 expressed interest in pursuing a course in biology in the future without AR.

### DISCUSSION

AR is unquestionably changing the learning environment both regionally and globally. Saudi Arabia cannot ignore the need to improve its learning environment. Kesim and Ozarslan (2012) believe that augmented reality technologies bring a more modernized and interesting learning experience to classrooms in contrast to the dull traditional textbook-based educational approach. Augmented reality involves the superimposition of computer-generated videos or images on an individual's perception of the true or real work; thus, it offers a fused composite view (Charles 2012).

Anatomy 4 Duses Android OS to improve visualization of the heart and other anatomical organs. The AR technology-based device allows learners to freely interact with the anatomical features of the human body. It improves their memory and provokes interest in the subject (Hou et al. 2013). As discussed in the introduction, the application needs students to first draw a blueprint image (4D) of the heart or human body parts from the software's library; these are mainly present in their phones or tablets. The application then uses the camera mounted on the gadget to create a three-dimensional virtually-real image (Educational Appstore n.d.).

This study shows that Anatomy 4D technologies offer a wide range of possibilities for tutors to develop and advance the learning experiences of students. As stated by Sural (2017), the three primary benefits include improvement of student performance, a rise in motivation, and an increase in interest to pursue the subject in the future. Thus, AR can essentially inspire and encourage learning experiences in traditionally monotonous classroom environments. For example, approximately 80 percent of students

were highly motivated when AR was used in teaching, but only two percent was less motivated. In contrast, only 23 percent was highly motivated when the traditional chalkboard and textbooks were used. Similarly, the performance of students was exemplary when the technology was used. For instance, 16 individuals scored above 50 percent when AR was used compared to only 8 when the technology was absent. On average, 43 students registered 50 percent and above when Aras used; only 18 percent achieved the 50 percent mark with traditional methods. AR could also impact the career choices of students. Similar to Khan et al. (2019) findings, most expressed the desire to pursue biology-related courses like medicine when introduced to the AR technology in class. For instance, 12 year-three students reported an interest in pursuing higher studies in biology in the future when exposed to the AR learning technique. Only five were interested without AR. All of these outcomes point to one fact: AR is critical to education in the 21<sup>st</sup> century and will continuously shape student achievement, motivation, and interest.

### CONCLUSION

The study reveals that the score of the majority of students in each particular year is above 50 percent when Anatomy 4D is used as part of the lesson, contrary to the traditional methods such as blackboard and textbooks, where the score was below average. The score was high since Anatomy 4D technique motivates students to participate in biology lessons to experience the use of AR technology. Only 23 percent of the students were interested in learning biology using chalkboard and textbooks compared to 80 percent motivated by Anatomy 4D. The findings reveal that AR technologies such as the Anatomy 4D can transform the education environment in Saudi Arabia and improve its current global rankings, particularly in mathematics and sciences. However, it can also transform each session into a new exciting experience for learners and can potentially maintain their morale and enthusiasm. Besides just enhancing their class achievement and memory, AR technologies can change the attitude of the Saudi students towards STEM subjects. The action promotes socio-economic development in the region.

## RECOMMENDATIONS

The study reports that 80 percent of the students were motivated by Anatomy 4D to participate in biology learning. Only two percent of the tested population showed less interest in using AR technology. When choosing teaching methods and tools, it is important to consider students' interest to ensure that the technique is effective. Therefore, the researcher recommends that education stakeholders consider and implement beneficial applications such as Anatomy 4D to increase student participation, learning, and performance.

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