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AUGMENTED REALITY FOR LEARNING HUMAN BODY ANATOMY AND TOTAL HIP REPLACEMENT SURGERY

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***Abstract*- Augmented Reality (AR) refers to a technology that enables users to superimpose digital material (images, audio, and text) on top of a physical environment. The science of human anatomy is the study of the body's structure and the human body's organs' functions. The traditional learning method of human anatomy is based on textbooks and plastic models. The student still faces problems with understanding human anatomy based on these methods. This study aims to create an augmented reality application to address the challenge of seeing and imagining complicated human body anatomy, and also help students to understand the procedure of Total Hip Replacement (THR) surgery and to explore the medical devices used in this surgery. Through the use of an augmented reality-based application, learning human anatomy and the procedure of the surgery will be more pleasant and interactive. AR application was developed using unity3D and Vuforia and then tested using an IOS device. In this AR application, the user performs total hip joint replacement surgery procedures and interactively explores human anatomy. Also, the user may test their knowledge with a quiz about the THR surgery procedure. The Research results show that the AR application received a SUS score of (82.125), indicating that it is user-friendly, recommended, and good according to the SUS range. Additionally, the application helps the students to understand the human anatomy and the procedure of total hip replacement surgery.**

***keywords:* Augmented reality, Medical training, Human anatomy, AR education.**

I. INTRODUCTION

Augmentation, by the Oxford dictionary, is explicated as an action where something is enriched, increased, or enlarged. Conversely, Augmented Reality (AR), according to the British Computer Society, explains as the "augmentation of real-life experience through the integration of the physical world with the digital one" [1]. AR technology has experienced a speedy rate of development and incorporating the medical learning process with this technology, AR's advancement has integrated closely every spectrum of life. Textbooks, text and image media, and statue models are now used by students learning human anatomy [2]. According toto this, studying a body structure is referred to as human anatomy. As to be perceived, the human body is a constituent of countless elements, which are made up of cells and tissues. Additionally, the attendance of lectures courses is considered a way to apprehend the structure of the human body. Nonetheless, standard textbooks of human anatomy bring about 2D images strapped for graphical data that cannot exude requisite information to learners. This is despite having a narrative expression [3]. It is challenging for students to visualize Two-dimensional to Three-dimensional materials while studying human anatomy using textbooks or plastic models. This study suggests using AR to teach human anatomy and the procedures of total hip replacement surgery. This kind of learning may help students learn better by combining text and Three-dimensional models. AR aims to bring virtual Three-dimensional imagery into the actual environment [4]. In this paper, The issue of the present learning method was examined. In particular, this paper focused on developing an AR-based application for teaching human body anatomy and the procedures of total hip replacement surgery. The goal is to make it easier to grasp the architecture of the human body, which will lead to a better

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knowledge of complete hip joint replacement surgery. Trainees and students can interact with human organs to gain further information about the selected organ in a 3D form beforeundertaking complete hip joint replacement surgery using the suggested technology.

II. Related Works

Different researches have been conducted on the subject of AR in the medical field, and these researches can be summarized as follows:

The authors in [5] designed an AR application to study the anatomy of the human heart through a web platform. It utilized two perspectives to evaluate the application. The first perspective involved an investigator evaluating the practicability of the human heart's 3D module. For the Second, usability concerns are assessed through the cognitive walkthrough approach. The authors application was developed only for the web. There is no mobile device that supports it, and many features of AR applications support only IOS and android systems. Researchers in [6] developed an AR application capable of segmenting and describing anatomical components for medical education. They indicated that Interactive Visualization Techniques such as VR and AR could be of help for searching information in biological and medical databases in an interactive way. The authors investigated the use of AR to help teach anatomy using the human elbow and a cat's organs as case examples. To evaluate the application, the Likert Scale was used. In the course of their work in [7], researchers designed an AR application for Human Anatomy. It's aimed to capture a particular picture from an anatomy atlas then convert it to a vibrant 3D design. For the students learning, it enhances their interactivity. This study's research technique is quantitative, collecting data and then developing a prototype to verify the impact. The researchers did not mention the software that was used to develop the web application. The drawback of this work is that it's available only on the web there is no mobile support, so many AR features will be missing. The researchers in [8] found that the problem of students experiencing difficulties in understanding human anatomy due to constraints of visualization from 2D to 3D images, so they developed an AR application for human body anatomy. The results of the research suggest that creating an AR application may help and improve student learning by making it more interactive, simpler, and pleasant. This AR application is more geared towards children than it is for medical students. The application is very simple, and the user can display only 3d models without labeling. The researchers in [9] utilized AR to assist students in learning about the anatomy digestive system. The researchers built their application based on the Prometheus book and used it as an AR marker. The researchers study the case of how distance can affect for detection of features. And they found 45 cm is the maximum distance the application can detect. The researchers have not used any evaluation method for the application. The researchers in [10] have presented four applications developed through AR for eLearning two focused on the collaborative work of students and two on biology and geography. The researchers were deduced that one of the contributions of the use of images, 3D models, sounds, and animations is that it attracts more students than classical teaching methods. Additionally, these augmented elements also allow students to retain new information more easily, and tests designed as games contribute to reducing their stress.

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III. Total Hip Joint Replacement Surgery Procedure

The procedure for total hip arthroplasty surgery is described briefly in this section [11], [12]. Fig. 1 sheds light on the various steps mentioned below:

1) The incision is made at the back or side of the hip.
2) The skin, muscle, and other tissue of the hip joint are opened, exposing the joint bones.
3) The surgeon dislocates the joint by removing the pelvic bone from its pelvic socket during the surgery.
4) A bone saw is used to remove the damaged femoral head from the hip joint.
5) The surgeon grinds and shapes the acetabulum in preparation for the acetabular cup prosthesis using a hemispheric reamer.
6) The acetabular cup is fixed into the modified socket.
7) During this procedure, the surgeon will put a circular plastic liner into the acetabular cup to help support the joint.
8) A replacement femoral stem is implanted after the femur bone has been prepped.
9) A provisional prosthetic ball is connected to the femoral stem for the remainder of the procedure.
10) To prevent the hip joint from dislocating, the surgeon will insert a provisional ball into the newly created socket.
11) The procedure will end by removing the temporary component and putting the ball into the socket. Finally, the surgeon will examine the joint for ease of movement, risk of dislocation and ensure correct hip anatomy by considering leg length and other factors.

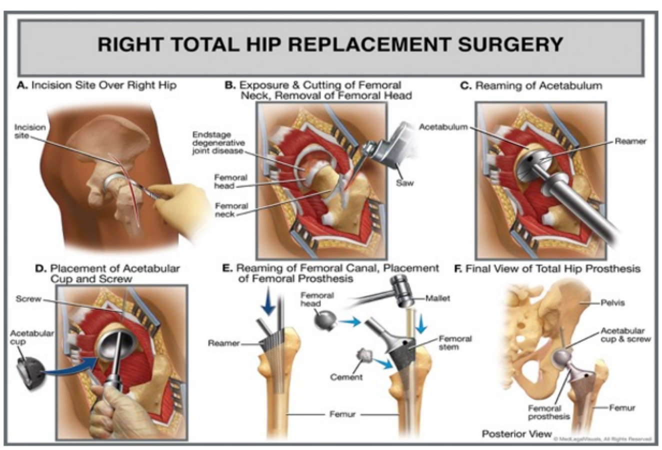

Figure 1: Total hip arthroplasty

IV. Proposed System

The AR Application consists of three parts: The anatomy part, the Surgery part, and finally, the Quiz part. Fig. 2 shows the proposed surgery room. In the surgery part, the user will use an AR marker-base to perform the total hip replacement surgery procedure. Each card is equipped with three virtual buttons, and each of these buttons performs different work. The virtual button was used to view the object's description, functions, and expanded version. The surgery room contains

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all required medical instruments used in this surgery. THR surgery requires extreme accuracy, and even a tiny error may result in severe harmso that the medical student must understand each step of the THR procedure before performing it on the patient.

Figure 2: The proposed surgery room, which the user uses in an AR environment

In the anatomy part, the user will examine the patient's case and see the damaged part. Then the user can check their information based on the case already seen. Fig. 3 shows the proposed anatomy room.

Figure 3: The proposed anatomy room, which the user uses in an AR environment to examine the patient's case

While in the quiz part, the user may test their knowledge with a quiz about the THR surgery procedure. For each question, there is a timer and a score; as soon as the user finishes all questions, the user can see the total score. Fig. 4 shows the proposed Quiz part design.

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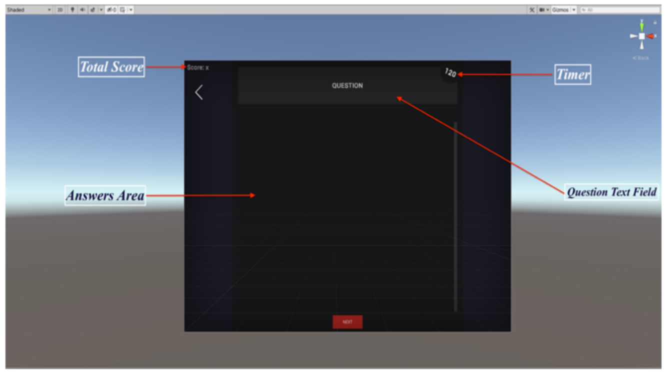

Figure 4: The proposed quiz part design

V. 3D-Model Preprocessing

All 3d models were prepared ahead of time. Blender Software and 3dx max were used to create each object used in the AR application. Also, this software was used to set the measurement of the surgery procedure. Fig. 5 shows the 3d model of Skelton editing in the Blinder software. Fig. 6 shows the 3d model of the Human body editing the cut of the hip and showing the implant in 3dx max.

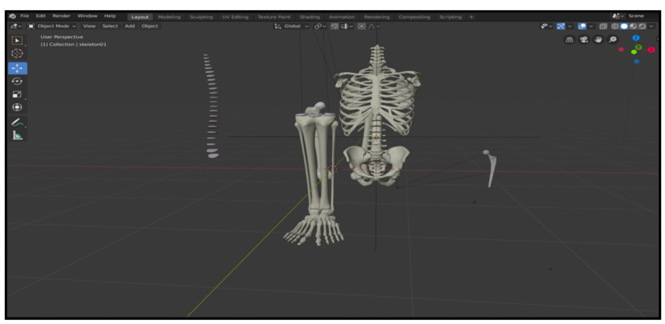

Figure 5: Three-dimensional model of human skeleton developed in blender software

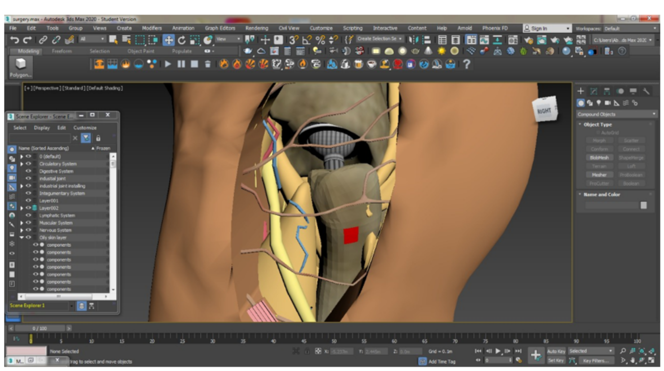

Figure 6: Three-dimensional model of the human organ's developed in 3dx max

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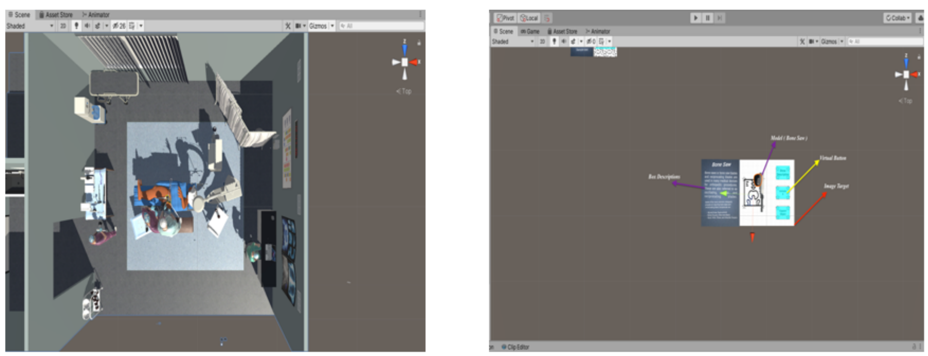
VI. THR SURGERY

Based on what was mentioned in Section III, nine surgical procedure stages must be performed in THR surgery. In this paper, Only one of these stages was explained in detail for brevity's sake. For this Stage, the acetabular reamer medical device card is picked up by the user. The acetabular reamer was set with the required animations and sound to reflect reality. Also, Rigidbody and box collider was set for the acetabular reamer card. The Collision occurs when the acetabular reamer cards are in the surgery room area. Once the Collision is detected between the Surgery room card and acetabular reamer, The user prepares the acetabulum for the acetabular cup prosthesis by grinding and shaping it with an acetabular reamer. The surgery room and all objects are shown in Fig. 7 (a) while the image target with the virtual buttons is shown in Fig. 7 (b). As the acetabular reaming begins, a colored Circle appeared on top of the patient's hip to indicate the progress of grinding and shaping the acetabular cup prosthesis. the colored circle disappearance indicates the end of the Stage. After that, a pop-up question appears to the user asking about a specific question related to this Stage. During the surgical procedure, there will be a simultaneously virtual monitoring device for a patient/s surgery in real life.



(a) (b)

Figure 7: (a) Surgery room with doctors and patient and all medical devices, (b) Medical device imposed over image target with three virtual buttons

VII. HUMAN ANATOMY

In this part, the user will see the objective case of a patient with a real X-ray. The 3D human model was set in this scenario with built-in medical information. The medical student's role is to make an accurate diagnosis based on the information provided. The user can scale, move, and rotate the 3d model to help him make the proper medical diagnosis. The user is then confronted with a pop-up question about the scenario presented. Depending on whether the user answer's right or wrong, the right button is highlighted in green; conversely, if the user answered incorrectly, then the right answer button is highlighted in green, and the wrong answers with red. After that, the user is presented with the explanation for selecting the correct answer in the question. Fig. 8 shows the general view of the question panel.

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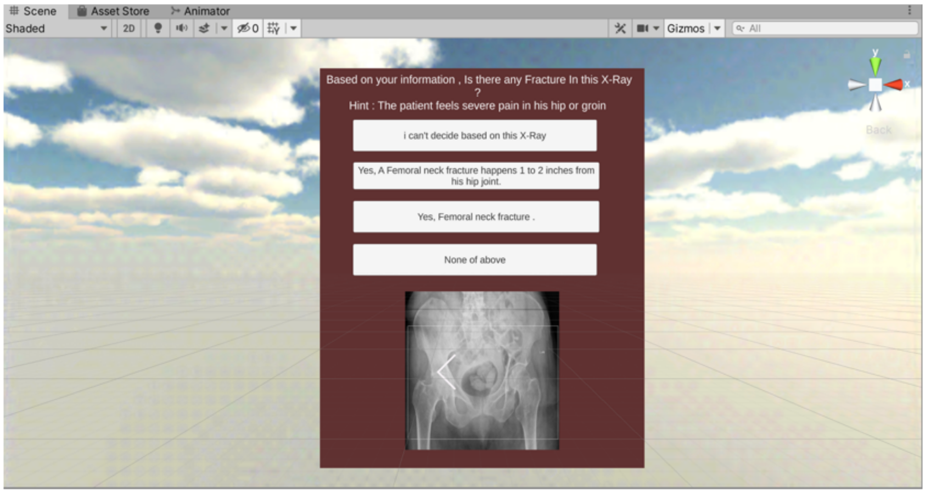

Figure 8: Canvas gameObject with question and answers fields that appear to user as a pop-up question

Based on Fig. 8, the canvas consists of the following components. The first component is a question which is a text mesh gameObject. The Second is the answer which is a button, and its characteristic is changed based on the user's choice.

VIII. Results

After the scene setup was completed, an IPad device was used to test the application. The result is shown below. Fig. 9 show most of the surgical medical device that is used in total hip joint replacement surgery. Each of these cards (image target) contains three virtual buttons. These cards are used to help students to explore the medical device from different aspects and read short descriptions before using it to perform virtual surgery. See Fig. 10 for more details about the virtual button.

Figure 9: Animated AR surgical instruments model imposed over image target

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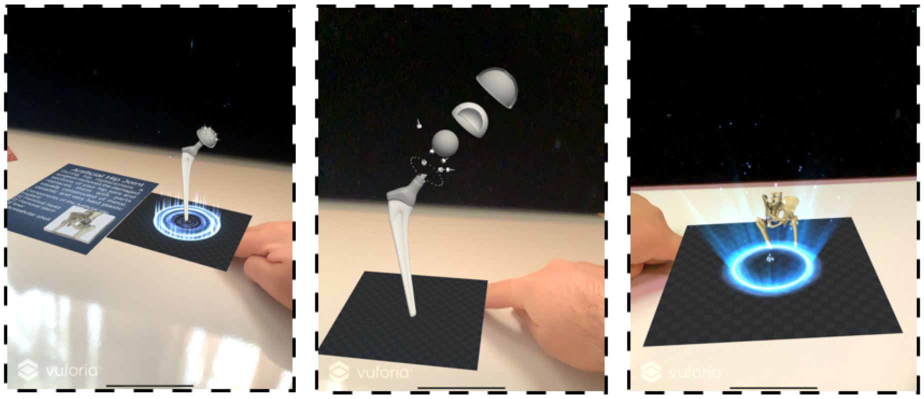
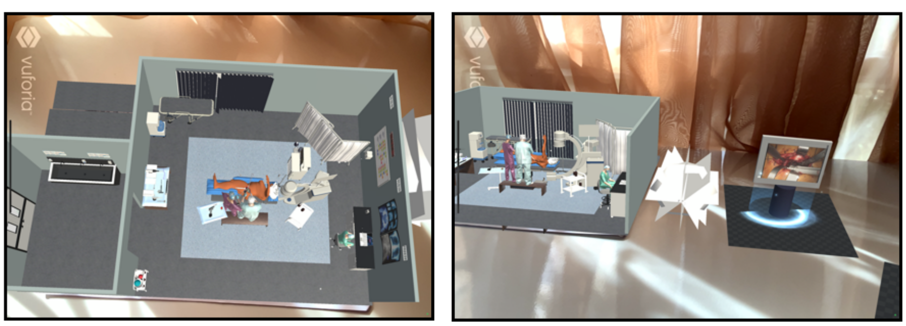


(a) (b) (c)

Figure 10: AR of artificial hip joint model imposed over image target with three virtual buttons (a) Model with description panel (b) Expanded version of model (c) Simple 3D video shows the function of the model

The application shows the surgical procedure of total hip joint replacement by using Collision between medical devices image target and surgery room target. Once the surgical device card is in the area of the surgery room, the Collision happenes, and the procedure begins. When the procedure begins the user can hear the sound of the medical device' and also see animations that reflect the device's work. This step may help students to be more involved in the surgery stage. Also, after the virtual surgeon completes the Surgical intervention pop-up questions appear to the student asking a specific question related to that stage. Fig. 11 (a) shows the progress of the surgery procedure stage. During the surgical procedure, there will be simultaneous monitoring for a patient/s surgery in real life see Fig. 11 (b). This monitoring helps to see exactly the step in real life.



(a) *(b)*

Figure 11: (a) AR surgery room model collides with acetabular reamer model,(b) Animated surgery room and monitoring device

Fig. 12 (a) shows the anatomy room with a 3D human model that is set in this scenario with built-in medical information (b) shows the anatomy room with a question based on user diagnosis. In this stage, the user examines the 3d model from

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different aspects and check the type of fracture so they can build the final diagnostic. Also the user can check the x-ray images that also help for the same reasons. Finally, Fig. 13 shows the quiz part, and the user will challenge himself with 14 questions about total hip joint replacement surgery and its procedure. As seen in the figure, the screen displays the score of the user and also a timer that helps to know the remaining time for each question. Since the question will be treated as false if the timer end and the user does not answer.

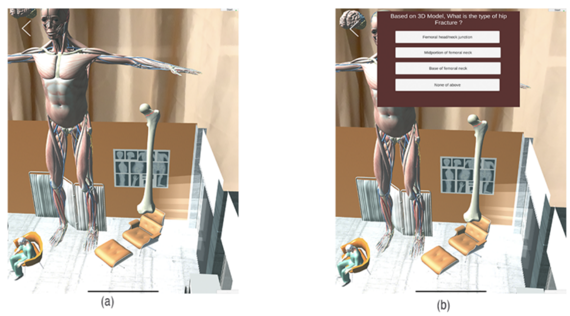

Figure 12: (a) Shows the anatomy room with a 3D human model (b) Shows the anatomy room with a question based on user diagnosis

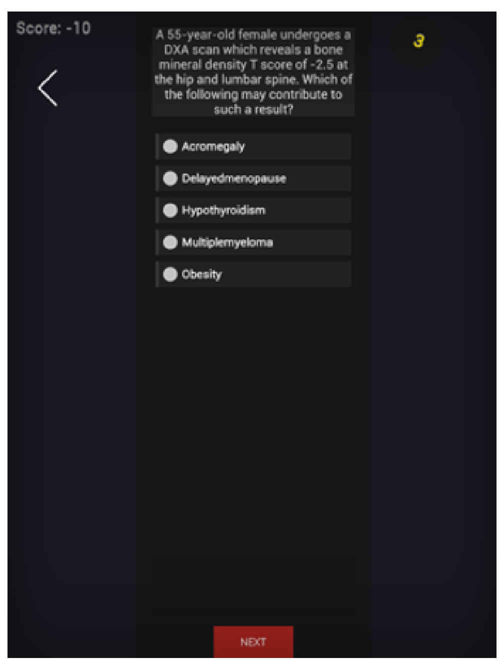

Figure 13: Quiz page in AR application

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IX. Evaluation of the application

The System Usability Scale (SUS) is used to assess the usability of the application [13], it is a very easy scale to administer to participants and Can be used on small sample sizes with reliable results. SUS is a trustworthy instrument for assessing the usability of applications. Also in this section, the findings of this study will be presented. For each SUS statement, the first column (Average Score $*$) the Scale is (1: strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, 5: strongly agree) Each statement has a scoring ($*$) scale from 1 (strongly disagree) to 5 (strongly agree). To determine the SUS's converted score ($**$), The following steps were used [12]:

1) For the odd numbers of SUS statements (9, 7, 5, and 1), the converted score is the

$$Converted\,Score = Average\,Score - 1 \tag{1}$$

2) For the even numbers of SUS statements (10, 8, 6, 4, and 2)

$$Converted\,Score = 5 - Average\,Score \tag{2}$$

Every Converted Score ($**$) Scale will have a value between 0 and 4. To determine the total value of SUS

$$Total\,Value\,of\,SUS = SUM * 2.5 \tag{3}$$

TABLE I
System usability scale evaluation

No.		Average Score (*)	Converted Score (**)
1	I think that I would Like to use the application frequently	4.3	3.3
2	I found the application is unnecessarily complex	2.1	2.9
3	I thought the application is easy to use	4.1	3.1
4	i think that I would Need technical support to use the application	1.33	3.67
5	i found the various functions in this application are well integrated	4.3	3.3
6	I thought there was too much inconsistency in the application	1.5	3.5
7	I would imagine that most people would learn to use the application very quickly	4.2	3.2
8	i found the application is very cumbersome / awkward to use	1.72	3.28
9	I felt Very conCident using the application	4	3
10	I needed to learn a lot of things before using the application	1.4	3.6
	SUM		32.85
	SUS Value (SUM X 2.5)		82.125

Feedback from the survey was predominantly positive (as seen in Table I). After applying the usability scale with the study group, the average of the usability factors was calculated. The highlight with the highest average results was for the questions related to the usages and the advantages of application with an average of 4.3. Then the ease of use of the application with an average of 4.2, in the field of complexity the results come acceptable with an average of 1.4. after completing this demonstration session, The feedback from participants was very useful and will be used to improve the AR application in several aspects. According to SUS, the score of 80.3 or above indicates that the application is of excellent quality; users enjoy using the application and will suggest it to their friends if SUS has a rating of 68 or above, which indicates that it is also regarded as an excellent application but may be improved. Finally, a SUS number less than 68 indicates that the application has a high priority for correction and must fix it very fast. From Table I, and based on

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equations 1, 2, and 3 the AR application gets SUS score (82.125), indicating that it is recommended and good according to the System Usability Scale range.

X. Conclusion

This study helps medical students in learning human anatomy and surgical procedures for THR efficiently. In addition, the issues of the traditional learning method were examined. In particular, the study focused on developing an AR-based application, learning human anatomy, exploring human body organs, and the surgical procedure of the THR enjoyably and interactively. Finally, the student can take a quiz; The quiz questions vary between human anatomy, fracture types, diagnostics, and surgical procedure of THR. Ultimately the AR application was tested through a demonstration session where suggestions were offered to improve, and positive feedback was received. SUS was used to measure the application's usability, and the application received a SUS score (82.125) which means that the application is good and recommended. However, the existing application has some limitations based on the user's testing results, which could be developed in future works. Foremost, the application must include more interactive functions to make the student's experience more engaging. In addition, the feature needed is to allow the student to customize the 3D model based on their patient's information.

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