Hindawi
Advances in Human-Computer Interaction
Volume 2019, Article ID 7208494, 14 pages
https://doi.org/10.1155/2019/7208494

Research Article

The Impact of an Augmented Reality Application on Learning Motivation of Students

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Received 26 October 2018; Accepted 31 December 2018; Published 3 February 2019

Guest Editor: Francisca Rosique

The research on augmented reality applications in education is still in an early stage, and there is a lack of research on the effects and implications of augmented reality in the field of education. The purpose of this research was to measure and understand the impact of an augmented reality mobile application on the learning motivation of undergraduate health science students at the University of Cape Town. We extend previous research that looked specifically at the impact of augmented reality technology on student learning motivation. The intrinsic motivation theory was used to explain motivation in the context of learning. The attention, relevance, confidence, and satisfaction (ARCS) model guided the understanding of the impact of augmented reality on student motivation, and the Instructional Materials Motivation Survey was used to design the research instrument. The research examined the differences in student learning motivation before and after using the augmented reality mobile application. A total of 78 participants used the augmented reality mobile application and completed the preusage and postusage questionnaires. The results showed that using an augmented reality mobile application increased the learning motivation of students. The attention, satisfaction, and confidence factors of motivation were increased, and these results were found to be significant. Although the relevance factor showed a decrease it proved to be insignificant.

1. Introduction

The use of augmented reality (AR) in education is an important topic of research [1]. AR enables the addition of virtual objects into real environments to facilitate real-time interaction [2]. Research on AR applications in education is still in an early stage, and there is a lack of research on the effects and implications of AR in the field of education [3–5].

The use of AR has become more accessible as it no longer requires specialised equipment and may easily be used on mobile devices [3, 5]. Most people now own mobile devices, and the use of these devices has increased, thereby enabling greater access to AR [1, 6]. The applications for mobile AR in education are increasing rapidly [7], and the feasibility of mobile AR has increased due to advances in mobile technology [4, 8]. AR mobile applications are available for several areas of education [2], and education related AR applications are now more commonly found on mobile devices [4, 9].

The use of AR may increase student learning motivation and contribute to improved academic achievement [10, 11]. There is insufficient research on the impact of using mobile AR in education, and there is room to explore the potential of AR to improve student learning motivation and contribute to improved academic achievement [4, 7, 10]. "The potential of AR in education remains unexplored and, there is a limited amount of studies investigating student motivation with the use of AR" ([4], p. 587). This research extends previous studies performed in other countries that looked specifically at the impact of AR technology on student learning motivation [4, 8, 11–13], with a case study from a university in South Africa.

The purpose of this research was to measure the learning motivation of undergraduate health science students at the University of Cape Town (UCT) before and after using a particular AR mobile application. The main research question was as follows: *What are the differences in student learning motivation before and after using the AR mobile application?* The main research question was underpinned by several

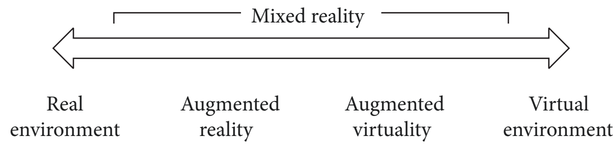

Figure 1: Milgram's mixed reality continuum [14].

subquestions examining how the attention, relevance, confidence, and satisfaction aspects of learning motivation were affected by using the AR mobile application. Empirical data was collected to answer these questions.

The remainder of this paper proceeds as follows. First, the conceptual background related to the use of AR in education and our theoretical model is presented. The next section discusses the methodology in detail, and this is followed by the analysis and research findings. Finally, implications are summarised, along with opportunities for future research.

2. Literature Review

The literature review includes literature published between 2013 and 2018 to ensure that the information included was recent and relevant. The Google Scholar H-5 index was used as the inclusion criterion for journals referenced [9].

2.1. Augmented Reality. AR combines real and virtual worlds, supplementing the real world with computer-generated virtual objects in real-time [1, 3, 12, 13, 18]. According to one of the most commonly accepted definitions, AR is said to be a technology that has three key requirements: combining of real and virtual objects in a real environment, aligning of real and virtual objects with each other, and real-time interaction [2, 4, 7, 14, 19]. Figure 1 shows Milgram's mixed reality continuum which is a taxonomy of the ways in which real and virtual elements may be combined [14]. The continuum ranges from a completely real environment to a completely virtual environment [5, 14]. Based on this continuum, mixed reality may be defined as a situation in which real and virtual objects are combined [5]. AR lies closer to the real environment end of the continuum as can be seen in Figure 1 [5, 14]. AR may be considered as a mixed reality technology which contains more reality, as this technology includes virtual objects in the user's real environment, enabling interaction with virtual content [1, 5, 7, 14]. In the case of mobile AR, the technology involves the addition of digital elements to the real world through a smartphone camera. Examples of mobile AR applications include Pokémon GO, which is a location-based mobile AR game that enables users to catch various digital Pokémon creatures around their area and AR GPS DRIVE/WALK NAVIGATION which provides an AR-powered navigation system [20]. Virtual reality differs from AR, as in virtual reality the real world is shut out and the user steps into a digital world using a virtual reality headset such as the Oculus Rift or Samsung Gear VR [21].

AR no longer requires specialised equipment and may easily be used through computers or mobile devices [3, 5]. A lightly AR supplements the real world with a relatively small amount of virtual information, while a heavily AR contains frequently accessible virtual information [5, 19]. The amount of virtuality within the real world determines the type of technology required to support the AR, as different display and tracking technologies result in different degrees of immersion [4, 5]. Immersive technologies such as head-mounted displays are used to support heavily AR and foster more immersion than mobile devices, which can support lightly AR [4, 5]. An example of a lightly AR would be the Pokémon GO mobile application, which can be used through a smartphone [20]. An example of a heavily AR is the Star Wars Jedi Challenges mobile application which requires the user to use a headset [22].

Many people now own mobile devices and therefore have access to AR [1, 6]. The use of AR for learning has been made more feasible due to advances in mobile technology and the increased use of smartphones [4, 8, 9, 18]. Smartphones and tablets are ideal to facilitate AR experiences, due to fast processors, graphics hardware, and various onboard sensors [18].

2.2. Augmented Reality in Education. The educational value of AR is closely linked to the way in which it is designed, implemented, and integrated into formal and informal learning environments [5]. An important consideration is how AR technologies support and afford meaningful learning [5]. Considering AR as a concept rather than a certain type of technology would be productive for educators [5]. The involvement of educators is important to facilitate the development of favourable AR applications for teaching, which increases the potential for AR to be incorporated in education [18]. AR applications have been developed for many areas of education [2].

Some of these AR applications have been used in previous studies [8, 11, 23]. Gopalan et al. [8] tested the impact of AR enhanced science textbooks on lower secondary school students in Malaysia. Chiang et al. [11] tested the use of an AR based mobile learning system for natural science inquiry activities on fourth-grade students in Taiwan. The system guided students towards target ecology areas and displayed the corresponding learning tasks or related learning materials [11]. Akçayır et al. [23] tested the use of an AR enhanced laboratory manual in science laboratories on first-year students in Turkey. This study tested the impact of the Anatomy 4D mobile application on the learning motivation of undergraduate health science students at UCT.

2.2.1. Advantages of Using Augmented Reality in Education. AR provides new ways of interacting with the real world and can create experiences that would not be possible in either a completely real or virtual world [3, 24]. AR has the unique ability to create immersive hybrid learning environments that combine real and virtual objects [3]. AR technologies enable users to experience scientific phenomena that are not possible in the real world, such as certain chemical reactions, making inaccessible subject matter available to students [3, 5, 23]. The manipulation of virtual objects and observation of phenomena that are difficult to observe in the real world can be facilitated through AR [5]. This type of learning experience can encourage thinking skills and increase conceptual understanding of phenomena that are either invisible or difficult to observe as well as correct any misconceptions [5]. AR addresses learning difficulties that are often encountered with visualising unobservable phenomena [5].

The skills and knowledge that students develop through technology-enhanced learning environments may be developed more effectively through AR technology [5]. The cognitive workload may be reduced by integrating multiple sources of information [3, 18]. The immersion and interaction features offered by AR may encourage students to engage in learning activities and may improve student motivation to learn [4, 8, 18]. AR provides highly interactive experiences and can generate authentic learner activity, interactivity, and a high level of realism [18]. Interaction with the world is important in the learning process, and, apart from reality, AR is one of the best ways of facilitating this interaction [18].

2.2.2. Challenges with the Use of Augmented Reality in Education. Users of AR technology may experience usability issues and technical problems, and some students may find this technology complicated [3]. One of the main challenges of AR applications is usability; however, ease of use is also reported as an advantage [3]. There is no evidence to suggest that usability issues are directly related to AR technology and may instead stem from inadequate technology experience, interface design errors, technical problems, or negative attitudes [3]. The combination of real and virtual objects may cause confusion as students may face difficulty navigating between fantasy and reality [5]. The use of AR technology within a learning environment requires multitasking, as students need to engage with large amounts of information and multiple technological devices to accomplish complex tasks [5]. This may result in a cognitive overload and a feeling of being overwhelmed or confused [3, 5]. The confusion indicates the authenticity of an AR system; however, this may be unproductive in a learning environment as students may lose track of the real environment [5]. Some studies report that AR decreases cognitive load, while others report cognitive overload [3, 5]. Schools may place constraints on the adoption of AR technology, and educators may be reluctant to use AR as this technology often requires innovative teaching approaches to be implemented [5]. The content available through AR applications is often inflexible, which restricts the teacher's control over the content and prevents adaptation to accommodate student needs [5]. The availability of authoring tools may resolve this challenge by allowing users to revise and create AR applications [5]. Another challenge may be that the stability of mobile AR technology is not guaranteed, and difficulties may be encountered if the technology lacks well-designed interfaces and guidance as this may result in the technology being too complicated [3, 5]. Users may also need time to get familiar and comfortable with AR technology [8].

2.3. Motivation in the Context of Learning. "Motivation provides a source of energy that is responsible for why learners decide to make an effort, how long they are willing to sustain an activity, how hard they are going to pursue it, and how connected they feel to the activity" ([4], p. 586). Motivation is a student's desire to engage in the learning environment [4, 18]. Motivation is necessary for students to make an effort towards learning and to increase academic performance [8], as motivation plays an important role in the learning process [12]. An important factor in increasing student motivation is the use of effective learning strategies [11]. Motivation is important in promoting and sustaining self-regulated learning, which often results in improved academic performance [4]. Students that are academically motivated tend to engage, persist, and expend effort to complete tasks compared to unmotivated students [4]. A lack of motivation could be a major obstacle to learner success, emphasising the importance of creating and sustaining motivation [4, 18].

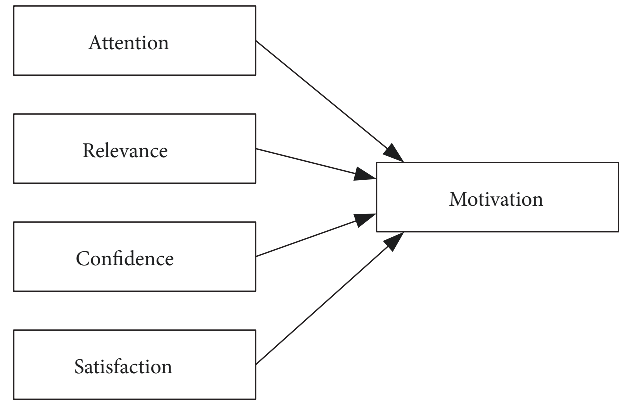

Figure 2: Keller's ARCS model of motivational design [15].

2.3.1. The Intrinsic Motivation Theory. The intrinsic motivation theory explains motivation in the context of learning [25]. Key factors that influence intrinsic motivation are challenge, curiosity, control, and fantasy [25]. Willpower and positive attitude are required to sustain motivation for learning [25]. Intrinsic motivation can influence students to participate in academic activities without external pressure or the expectation of external rewards [25]. Participation is influenced based on a desire to experience the fun, challenge, and uniqueness of the academic activity [25]. Studies have shown that AR can have consistent positive impacts on student motivation [4, 8, 11–13]. There are studies which prove that AR can specifically increase student motivation in science learning [8]. The increased student motivation may be largely attributed to the elements of curiosity, fantasy, and control presented using AR technology [26], as student motivation may be directly influenced using an attractive or stimulating medium or learning material [25].

This led to the main research question (RQ) (RQ 1): *What are the differences in student learning motivation before and after using the AR mobile application?* The attention, relevance, confidence, and satisfaction (ARCS) model was used to answer RQ 1.

2.4. ARCS Model. The attention, relevance, confidence, and satisfaction (ARCS) model of motivational design as shown in Figure 2 was used to understand the impact of AR technology on student motivation towards learning [4, 8, 11, 13]. Based on the ARCS model, the design of the AR technology must attract student *attention*, it must be *relevant* to the students, the students must be *confident* with the technology, and the students must feel *satisfied* after using the technology [11].

Based on the ARCS model, research questions (RQ) 2.1, 2.2, 2.3, and 2.4 were developed to determine the impact of using an AR mobile application on each of the ARCS factors [4, 8, 11, 13].

2.4.1. Attention. Attention can be gained through perceptual arousal or inquiry arousal [17, 27]. Perceptual arousal can be gained using novel, surprising, and uncertain events which hold attention. Inquiry arousal can be gained using challenging questions or problems which stimulate curiosity [4, 27]. Attention may be grabbed through a variety of methods including participation, humour, conflict, variety, and real-world examples [28]. The attention factor is the most important as it initiates the motivation for students [27]. Once interest has been created, students are usually willing to invest their time and pay attention [27].

Based on the attention factor, *research question 2.1 was proposed: How was the attention aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application?*

2.4.2. Relevance. Relevance can be established through using language and examples that are familiar to the students [17, 27]. Strategies to achieve relevance include goal orientation, motive matching, and familiarity [27]. Goal orientation can be achieved by making students aware of how the knowledge will help the student today as well as in the future [17, 27]. Motive matching involves assessing the students' needs and reasons for learning to provide choices that are conducive to their motives [27]. Familiarity involves providing examples that tie in with the student's experience and relate to the subject matter [27]. Pappas [28] mentions links to previous experience, perceived present worth, perceived future usefulness, modelling, and choice as strategies to establish relevance. Studies reported that a benefit of AR technology is the ability to provide immediate and relevant information and guidance [8, 11].

Based on the relevance factor, *research question 2.2 was proposed: How was the relevance aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application?*

2.4.3. Confidence. Confidence involves establishing positive expectations for achieving success among students [27]. The confidence level is often correlated with motivation; therefore, it is important that the design of lessons provides students with a method for estimating the probability of their success [27]. Examples include a syllabus and grading policy, rubrics, or a time estimate in which to complete tasks [27]. Confidence may be built through timely and relevant feedback which provides positive reinforcement for personal achievements [27]. Pappas [28] mentions facilitating self-growth, communicating objectives, providing feedback, and giving learners control as ways to raise confidence.

Based on the confidence factor, *research question 2.3 was proposed: How was the confidence aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application?*

2.4.4. Satisfaction. Students must obtain some type of reward from learning experiences [27]. Satisfaction may be in the form of a sense of achievement, praise, or entertainment [27]. Feedback and reinforcement are also important elements [27]. Satisfaction is based upon motivation, and, to keep students satisfied, they should be given the opportunity to use (or apply) their newly learned skills as soon as possible in a relevant setting [27]. Pappas mentions [28] praise or rewards and immediate application as ways to increase satisfaction.

Based on the satisfaction factor, *research question 2.4 was proposed: How was the satisfaction aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application?*

2.5. Instructional Materials Motivation Survey. The Instructional Materials Motivation Survey (IMMS) was developed to measure student learning motivation following the ARCS model [11, 13]. Appendix A shows the IMMS, and Appendix B shows the scoring guide for the IMMS [17]. The scoring guide shows which statements in the IMMS relate to each of the four ARCS factors and highlights the statements that have been stated in a negative manner. The IMMS is "a 36-item situational measure of people's reactions to instructional materials" ([29], p. 204); the IMMS has been used as a pre- and postinstrument to test motivational needs and reactions to a new technology such as AR [29]. The IMMS instrument has been validated and successfully used in several previous research studies assessing the impact of the use of technology on student learning motivation [4]. Previous studies have used the IMMS to develop questionnaires in the form of a five-point Likert scale [4, 8, 13]. The "IMMS has a documented reliability coefficient of 0.96" ([4], p. 589); this can be seen in Appendix C along with the reliability coefficients for the attention, relevance, confidence, and satisfaction measures. In the papers by Wei et al. [18] and Solak and Cakir [13], the results of the IMMS questionnaire showed that student learning motivation improved significantly due to the introduction of AR technology. AR technology has been found to increase student learning motivation for attention, relevance, confidence, and satisfaction factors [4, 11]. The IMMS was used in this research and the results were analysed to answer the research questions.

3. Methodology

The intrinsic motivation theory was used to understand motivation in the context of learning [25]. The ARCS model of motivational design was used to understand the impact of AR technology on student motivation towards learning [4, 8, 11, 13]. The impact on student learning motivation was measured by comparing the learning motivation of students before and after using an AR mobile application, using a preusage and postusage questionnaire.

The target participants were undergraduate health science students at UCT, studying towards a Bachelor of Medicine and Bachelor of Surgery (MBChB). The target participants were taking an anatomy course offered by the UCT Department of Human Biology. The department had not found or used any AR mobile applications prior to this study. Approval for the students to use the application was obtained from the course convenor.

The numbers of participants used by Budiman [12], Chiang et al. [11], Di Serio et al. [4], Gopalan et al. [8], and Solak and Cakir [13] were 112, 57, 69, 70, and 130, respectively. The sample size for this research was 78 participants who used the AR mobile application and completed the preusage and postusage questionnaires. This sample size is close to the average sample size of 87.6 calculated based on the five previous studies which also investigated the impact of using AR on student motivation.

The participants could not be separated into a control and experimental group following the design of many previous studies (e.g., [8, 11, 13]), as this could result in some students obtaining an unfair (dis)advantage in the course. The curriculum provides students with a detailed understanding of the normal structure and function of the human body and how these are affected when the body suffers from disease. The impact of disease and the role of healthcare services are studied in a case-based group learning manner, supported by lecturers and practical sessions. Students learn core material as well as clinical skills, interpretation of data, professional values and ethics, and certain procedural skills directly related to the cases studied. Therefore, data collection was based on the procedure used by Di Serio et al. [4] where quantitative data was collected in two steps using a preusage and postusage questionnaire.

3.1. Research Instruments. A preusage and postusage questionnaire were used as instruments for data collection. The questionnaires were in the form of a five-point Likert scale and were designed based on the IMMS used in previous studies [4, 8, 13]. IMMS was chosen based on the successful use in previous studies to determine the impact of AR technology on student motivation [4, 8, 11, 13].

All the questions in the preusage questionnaire were related to student motivation regarding the use of the anatomy notes for the course, which included a textbook and lecture slides. All the questions in the postusage questionnaire were related to student motivation regarding the use of the Anatomy 4D mobile application. The questionnaires were submitted for ethical approval before conducting data collection. Appendix D shows the questions for the preusage questionnaire and Appendix E shows the questions for the postusage questionnaire. Ethics approval was obtained from the university before proceeding with data collection. The participants were required to provide consent before completing the preusage and postusage questionnaire and the anonymity of all respondents was ensured as no personally identifiable information was requested or captured.

In addition, Google Forms was used to create and distribute a short online interview that consisted of six open-ended questions. This online interview was distributed to two lecturers in the UCT Faculty of Health Sciences. The purpose of this online interview was to gain insight into the views of these lecturers regarding the use of AR.

3.2. AR Mobile Application. In previous studies the AR educational tools used were designed specifically for the courses [4, 8, 11, 13, 23]. The AR mobile application used in this study was not designed specifically for the course; instead the Anatomy 4D mobile application designed by DAQRI was used as the educational AR tool [16, 30]. The relevance of this mobile application to second-year MBChB students was verified by a course convenor in the UCT Faculty of Health Sciences prior to the study.

Anatomy 4D is a free application that uses AR to enable interaction with pictures of the human body. The application uses a target image, shown in Figure 3, and the camera on a mobile device to display an AR model of the human body [16]. A screenshot of the Anatomy 4D mobile application is displayed in Figure 4 [16]. The Anatomy 4D mobile application was chosen based on its accessibility. All participants used both the anatomy notes as well as the AR mobile education application.

4. Data Analysis

Empirical data were analysed following the methods used by Chiang et al. [11], Di Serio et al. [4], Gopalan et al. [8], Keller [17], and Solak and Cakir [13]. The overall mean values of the preusage and postusage questionnaire were used to compare student learning motivation and to determine if there was a statistically significant difference in motivation [4].

The Cronbach alpha values were calculated for both the preusage and postusage questionnaires to determine the reliability of the results, based on the use of this test by Chiang et al. [11], Gopalan et al. [8], and Solak and Cakir [13]. Mean values were calculated for both the preusage and postusage questionnaires for the four factors that measured student motivation based on the ARCS model [4, 17]. The significance of the difference between mean values for the four factors was determined and the differences in mean values were compared to answer the research questions.

The results were used to determine if there was a statistically significant difference for any of the four factors [4]. A statistically significant difference indicates how much each of the four factors of motivation was impacted using an AR mobile application.

Before performing analysis, the data collected from the preusage and postusage questionnaires was exported to Microsoft Excel. The questionnaires contained some questions that were stated in a negative manner, indicated in Appendix B which shows the scoring guide for the IMMS. The values for these questions were recoded before the mean value for each ARCS factor and the overall mean values were calculated [17].

4.1. Questionnaires. Microsoft Excel was used to calculate the mean value for each ARCS factor for both the preusage and postusage questionnaires. The calculated values are displayed in Table 1; the percentage differences indicate that

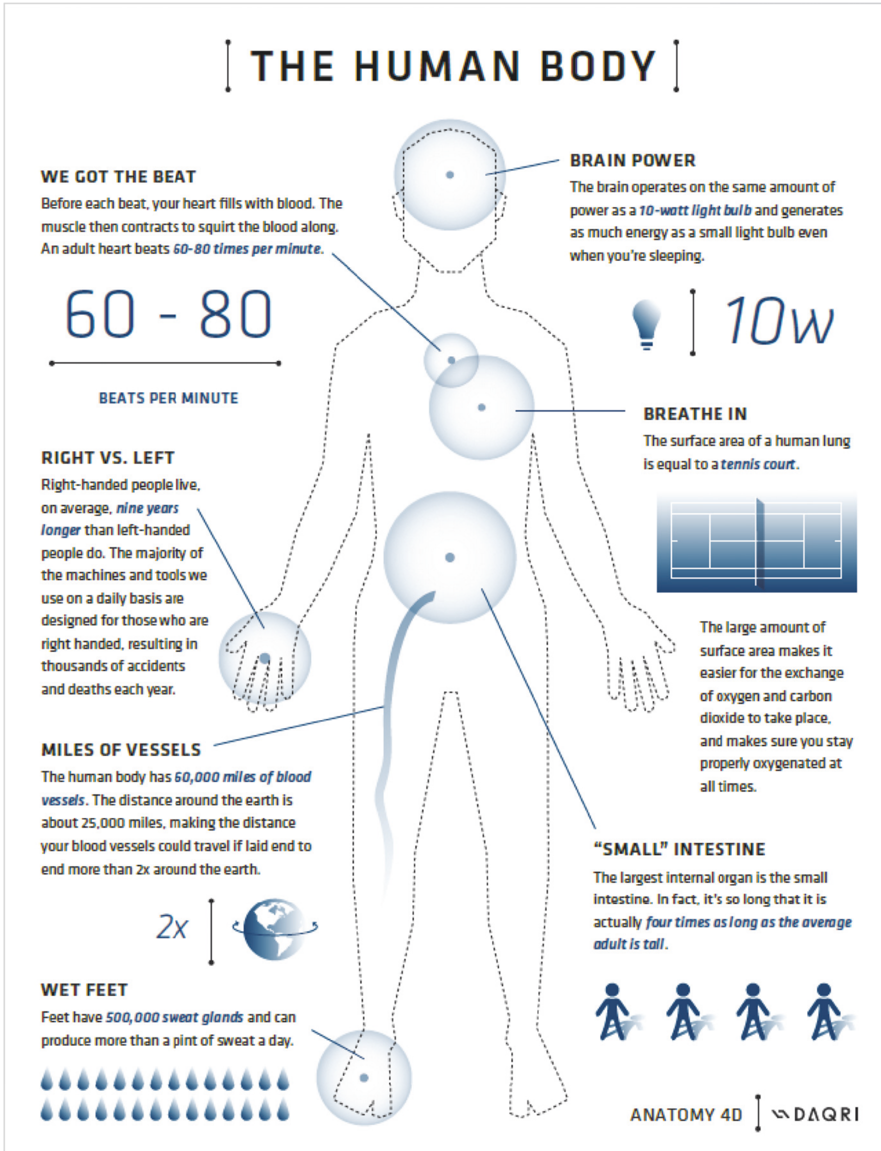

Figure 3: Anatomy 4D target image [16].

Table 1: Mean values for ARCS factors.

	Preusage	Postusage	Percentage difference
Attention	2.93	3.83	30.72% increase
Relevance	3.37	3.26	3.26% decrease
Confidence	2.98	3.30	10.74% increase
Satisfaction	2.96	3.33	12.50% increase
Overall	3.05	3.49	14.43% increase

the mean values for attention, confidence, and satisfaction increased while the relevance factor decreased. This allows a comparison of the learning motivation of students before and after using the AR mobile application.

Although the postusage mean values for each ARCS factor and the overall mean value showed either an increase or decrease, it was necessary to determine whether the change in each mean value was significant. Significance indicates that the difference in mean value is greater than a value that would be expected by chance [31]. The null hypotheses for each factor were that the postusage mean value was equal to the preusage mean value. A significance level of 0.05 was used; therefore p values less than 0.05 were considered significant while p values greater than 0.05 were considered insignificant [31]. The probability for each ARCS factor was computed using the central limit theorem where a value for z was obtained [31]. The p value was then obtained using the z tables [31]. The calculation results and p values for each ARCS factor are shown in Table 2. The overall mean value obtained for

Figure 4: Anatomy 4D mobile application screenshot [16].

the postusage questionnaire was 14% higher than the value obtained for the preusage questionnaire.

The comparison of mean values for the preusage and postusage questionnaires is shown in Figure 5.

A Cronbach alpha test was performed using IBM SPSS to measure the reliability of the results for each ARCS factor and the overall reliability. IBM SPSS was used by Akçayır et al. [23] and Gopalan et al. [8]. The Cronbach alpha reliability test was used to see how well the questions for each ARCS construct fit together. Cronbach's alpha is a measure of internal consistency: an alpha score of 0.7 or higher is regarded as acceptable, an alpha score of 0.8 or higher is regarded as good, and an alpha score of 0.9 or higher is regarded as excellent [32]. The Cronbach alpha values for each ARCS factor and the total scale are displayed in Table 3.

4.2. Online Interviews. In addition to collecting data from student participants in the course, two lecturers in the UCT Faculty of Health Sciences were also interviewed. The interview was conducted online and consisted of open-ended questions. Of interest were their views regarding the use of AR in the classroom.

Lecturer X in the Division of Anatomical Pathology and Lecturer Y in the Division of Clinical Anatomy and Biological Anthropology in the UCT Department of Health Sciences were interviewed. Both lecturers support the use of AR to teach health science courses at UCT as Lecturer X said that "*students are often attracted by the use of technology as a learning tool*" and "*augmented reality may prove to be useful in teaching anatomy and anatomical pathology*." However, Lecturer X also stated that "*although AR represents an exciting new technology in Higher Education, we should caution ourselves against embracing it blindly*." Although Lecturer X stated that "*the advantages [of AR] cannot be stated at this point*," Lecturer Y stated that the advantages of augmented reality include "*making learning fun, appealing to multiple learning styles and increasing motivation to learn*."

"*Tools should be critically examined and researched in order to weigh their potential benefits, the advantages [of AR] cannot be stated at this point. Research will need to be conducted at the time of implementation, to see if it does offer advantages to higher education teaching and learning in the Health Sciences*." Challenges highlighted by the lecturers include

(i) training of staff and students on the application of the equipment

(ii) technical difficulties

(iii) possessing of a support team to assist with necessary software and hardware

(iv) access to internet off campus

The lecturers stated that AR may improve student motivation towards learning as it could "*make learning more enjoyable and interactive*" and be "*a 'fun' way to learn*." "*Augmented reality could improve student's intrinsic motivation towards learning. However, it must be stated that this is speculative, and research would be the only reliable way to answer this question*." Lecturer X "*would like to explore the use of a smartphone app, that could be used to bring AR into the Pathology Learning Centre*." In contrast, Lecturer Y would "*recommend [AR] as an additional resource*" and views AR "*as a helpful and attractive additional learning resource*."

5. Discussion of Findings

The overall Cronbach alpha value and the Cronbach alpha values obtained for each ARCS factor were all greater than 0.7. An alpha score greater than or equal to 0.7 indicates an acceptable value, while an alpha value of 0.8 or higher indicates a good value [32]. Therefore, the Cronbach alpha values obtained indicate that the results obtained were reliable [32]. Obtaining reliable data that return Cronbach alpha values exceeding 0.7 is consistent with findings from previous studies [8, 11, 13]. The reliability of the data was

Table 2: Significance of differences in mean values.

Attention	
Hypotheses	$H_0: \mu = 2.93$; $H_1: \mu > 2.93$
Calculation	$P(\times > 2.93) = P\left(z > \dfrac{3.83 - 2.93}{1.13 \div \sqrt{78}}\right) = P(z > 7.03)$
***p* value**	p value < 0.00001
Significance	The result is significant at $p < 0.05$
Relevance	
Hypotheses	$H_0: \mu = 3.37$; $H_1: \mu < 3.37$
Calculation	$P(\times < 3.37) = P\left(z > \dfrac{3.26 - 3.37}{1.13 \div \sqrt{78}}\right) = P(z > -0.76)$
***p* value**	p value $= 0.223$
Significance	The result is not significant at $p < 0.05$
Confidence	
Hypotheses	$H_0: \mu = 2.98$; $H_1: \mu > 2.98$
Calculation	$P(\times > 2.98) = P\left(z > \dfrac{3.30 - 2.98}{1.30 \div \sqrt{78}}\right) = P(z > 2.17)$
***p* value**	p value $= 0.015$
Significance	The result is significant at $p < 0.05$
Satisfaction	
Hypotheses	$H_0: \mu = 2.96$; $H_1: \mu > 2.96$
Calculation	$P(\times > 2.96) = P\left(z > \dfrac{3.33 - 2.96}{1.34 \div \sqrt{78}}\right) = P(z > 2.44)$
***p* value**	p value $= 0.0073$
Significance	The result is significant at $p < 0.05$
Overall	
Hypotheses	$H_0: \mu = 3.05$; $H_1: \mu > 3.49$
Calculation	$P(\times > 2.96) = P\left(z > \dfrac{3.49 - 3.05}{1.27 \div \sqrt{78}}\right) = P(z > 3.06)$
***p* value**	p value $= 0.001107$
Significance	The result is significant at $p < 0.05$

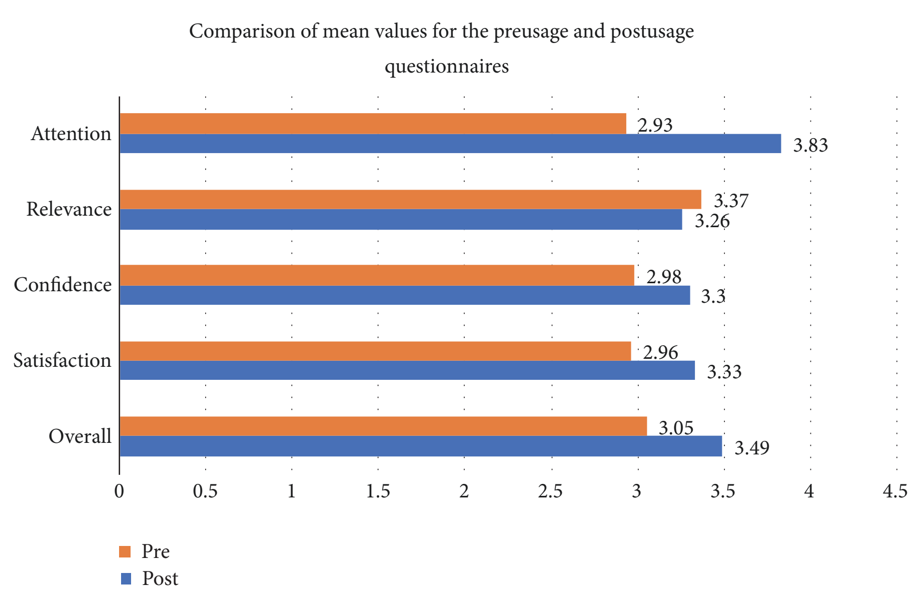

Figure 5: Comparison of mean values for the preusage and postusage questionnaires.

Table 3: Cronbach alpha values.

ARCS subscales	Cronbach alpha values
Attention	0.845
Relevance	0.836
Confidence	0.840
Satisfaction	0.744
Total scale	0.833

expected, given the high Cronbach alpha values of the Instructional Materials Motivation Survey (IMMS) upon which the preusage and postusage questionnaires were based. The values for the reliability estimates of the IMMS (all above 0.8) are shown in Appendix C while the Cronbach alpha values obtained for the findings (all above 0.7) are shown in Table 3.

Based on the information provided in Table 2, the significance of the change in mean value for each ARCS factor was determined. The increases in mean values for the attention, confidence, and satisfaction factors were significant at the 0.05 level. This indicated that the increase in mean values obtained for these factors was significant. The decrease in mean value for the relevance factor was not significant at the 0.05 level. Although the null hypothesis for the relevance factor could not be rejected, this did not mean that the null hypothesis held true [31]. This rather indicated that the decrease in mean value obtained was not significant. The results of the significance test indicate that the increases in mean values for the attention, confidence, and satisfaction factors are significant while the decrease in the mean value of the relevance factor is insignificant.

5.1. Advantages and Challenges. The lecturer in the Division of Anatomical Pathology, Lecturer X, did not outline any advantages of AR, stating that the "advantages cannot be stated" without conducting more research. However, Lecturer X did say that "augmented reality could improve student's intrinsic motivation towards learning." Lecturer Y stated that one of the advantages of augmented reality included "increased motivation to learn." According to Di Serio et al. [4], Gopalan et al. [8], and Wei et al. [18] the immersion and interaction features offered by AR may encourage students to engage in learning activities and may improve student motivation to learn. The data collected indicated that the use of AR did, in fact, increase the motivation to learn, or the intrinsic motivation, of the target participants.

One of the challenges highlighted by both lecturers was "technical difficulties," as reported by Akçayır and Akçayır [3]. Another challenge stated by Lecturer X was "training staff and students on the application of the equipment." This is related to the challenge outlined by Gopalan et al. [8] who stated that users may need time to get familiar and comfortable with AR technology.

5.2. Attention. The attention factor was used to measure the attention of students with regard to the prelearning material, the anatomy notes, and the postlearning material, the Anatomy 4D mobile application [11]. The 31% increase in the mean value was significant and indicated that the Anatomy 4D mobile application was better able to hold the attention of the students than the anatomy notes. The increase in attention indicated that perceptual arousal was gained using the Anatomy 4D mobile application which led to the increase in attention [17, 27]. The significant increase in attention is encouraging as the attention factor is the most important as it initiates the motivation for students [27]. RQ 2.1 asked, How was the *attention* aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application? Based on this finding, RQ 2.1 was answered: after using the AR mobile application, the attention aspect of learning motivation of UCT undergraduate health science students showed a significant increase of 31%.

5.3. Relevance. The relevance factor was used to measure the relevance of the prelearning material, the anatomy notes, and the postlearning material, the Anatomy 4D mobile application [11]. Relevance can be established through using language and examples that are familiar to the students [17, 27]. The 3% decrease in the mean value of relevance indicated that the Anatomy 4D mobile application was less relevant than the anatomy notes. The decrease in relevance indicated that students were more familiar with the anatomy notes than with the Anatomy 4D mobile application. The decrease in relevance may be attributed to the fact that the Anatomy 4D mobile application was not designed specifically for the course as in previous studies by Akçayır et al. [23], Chiang et al. [11], Di Serio et al. [4], Gopalan et al. [8], and Solak and Cakir [13]. However, the 3% decrease was found to be insignificant which indicated that the difference in mean value is not greater than a value that would be expected by chance [31]. This indicated that there was not sufficient evidence at the 0.05 level of significance to conclude that the decrease in the mean value of the relevance factor was significant. Therefore, the decrease observed in the mean value for the relevance factor was insignificant. Based on this, both the anatomy notes and the Anatomy 4D application showed relevance given the mean values of 3.37 and 3.26, respectively. RQ 2.2 asked, How was the relevance aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application? Based on this finding, RQ 2.2 was answered: after using the AR mobile application, the relevance aspect of learning motivation of UCT undergraduate health science students showed a slight decrease of 3%, which was found to be insignificant.

5.4. Confidence. The confidence factor was used to assess the confidence of students with regard to the prelearning material, the anatomy notes, and the postlearning material, the Anatomy 4D mobile application [11]. The increase of 11% in the mean value of confidence indicated that students felt more confident with the Anatomy 4D mobile application than the anatomy notes. The increase in confidence indicated that the Anatomy 4D mobile application may have established positive expectations for achieving success among students [27]. RQ 2.3 asked, How was the confidence aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application? Based on this

Table 4

	Di Serio et al. [4]	Chiang et al. [11]	This study	Variance with average
A	15%	11%	31%	+18%
R	5%	15%	-3%	-13%
C	7%	11%	11%	+2%
S	13%	11%	13%	+1%

finding, RQ 2.3 was answered: after using the AR mobile application, the confidence aspect of learning motivation of UCT undergraduate health science students showed a significant increase of 11%.

5.5. Satisfaction. The satisfaction factor was used to measure student satisfaction after using the prelearning material, the anatomy notes, and the postlearning material, the Anatomy 4D mobile application [11]. The increase in the mean value of satisfaction indicated that the students felt more satisfied after using the Anatomy 4D mobile application than when using the anatomy notes. Satisfaction may be in the form of a sense of achievement, praise, or entertainment [27]. The increase in satisfaction indicated that students were entertained using the Anatomy 4D mobile application [27]. RQ 2.4 asked, How was the satisfaction aspect of learning motivation of UCT undergraduate health science students affected by using the AR mobile application? Based on this finding, RQ 2.4 was answered: after using the AR mobile application, the satisfaction aspect of learning motivation of UCT undergraduate health science students showed a significant increase of 13%.

5.6. Summary. The use of the AR mobile application increased the motivation of the students by 14%. The attention, confidence, and satisfaction of the students were increased by 31%, 11%, and 13%, respectively, and these increases were found to be significant. The 3% decrease in the mean value of the relevance factor was found to be insignificant. The increase in the mean values of the attention, confidence, and satisfaction factors is an outcome that is consistent with previous studies. However, the decrease in relevance is an outcome that is not consistent with the results of previous studies. Di Serio et al. [4] found that the attention, relevance, confidence, and satisfaction factors were increased by 15%, 5%, 7%, and 13%, respectively. Chiang et al. [11] found that the attention, relevance, confidence, and satisfaction factors showed significant increases of 11%, 15%, 11%, and 11%, respectively. The 13% increase in satisfaction obtained was consistent with the 13% increase found by Di Serio et al. [4] and the 11% increase in confidence obtained was consistent with the 11% increase found by Chiang et al. [11] (see Table 4).

The overall mean values obtained are shown in Table 1. Based on these values and the mean values obtained for each ARCS factor, RQ 1 may be answered. Student learning motivation after using the AR mobile application was 14% higher than student learning motivation before using the Anatomy 4D mobile application. Therefore, using the Anatomy 4D mobile application had a positive impact on student learning motivation. The overall outcome of the research is consistent with previous studies which showed a positive impact on student learning motivation. Students were moderately motivated when using the anatomy notes and slightly more motivated when using the Anatomy 4D mobile application [4].

6. Conclusion

The objective of this research was to understand the impact of an AR mobile application on the learning motivation of undergraduate health science students at UCT. The literature indicated that there is insufficient research on the impact of using mobile AR in education, and there is room to explore the potential of AR to improve student learning motivation and contribute to improved academic achievement [4, 7, 10]. The literature review summarised various concepts which led to developing the research questions that were based on the attention, relevance, confidence, and satisfaction (ARCS) model of motivational design [17]. Augmented reality (AR) was defined as combining real and virtual worlds, supplementing the real world with computer-generated virtual objects in real-time [1, 3, 12, 13, 18], and AR was explained in the context of education. Mobile AR was discussed given that AR may easily be used through mobile devices [3, 5]. The design involved using the Anatomy 4D mobile application as the educational AR tool.

The literature review looked at the use of AR in education followed by an overview of some previous studies which used AR applications [8, 11, 23]. Various advantages and challenges of the use of AR in education were also discussed. Motivation in the context of learning and the intrinsic motivation theory, which was used to explain learning motivation, were then discussed [25]. This led to the main research question (RQ) (RQ 1): What are the differences in student learning motivation before and after using the AR mobile application? The ARCS model was used to answer RQ 1. The ARCS model and each ARCS factor was used to understand the impact of AR technology on student motivation towards learning [4, 8, 11, 13]. The Instructional Materials Motivation Survey (IMMS) was used to develop the instruments for this research [17].

The methodology and design of the research were discussed, as well as the methods of data collection and data analysis. The data analysis was used to interpret the findings to answer the research questions. The outcomes of this research showed that the use of an AR mobile application increased the learning motivation of undergraduate health science students at the University of Cape Town (UCT). The results are consistent with previous studies by Di Serio et al. [4], Chiang et al. [11], Gopalan et al. [8], and Solak and Cakir

[13]. The overall mean value obtained for the current teaching method was 3.05 and the overall mean value for the use of the Anatomy 4D mobile application was 3.49. An increase in the attention, confidence, and satisfaction factors was found after using the Anatomy 4D mobile application, while there was a decrease in the relevance factor.

The results of this study add to previous studies conducted to measure student learning motivation after using an AR educational tool. Similar research studies should be conducted over extended periods of time to reduce the novelty effect which may have acted as a disturbing factor [4]. This study along with many other previous studies has proved the contribution of AR technology in education; however, research on this topic is still in an early stage [13]. Further research should be conducted to determine which learning activities would benefit the most from AR technology [4]. Akçayır et al. [23], Chiang et al. [11], Ibáñez et al. [10], and Solak and Cakir [13] showed that AR tools had a positive impact on academic performance. Further research should be conducted to assess the impact of AR on academic performance, as suggested by Lecturer X who said, "research would need to be conducted as to whether it improves understanding of content, assessment performance etc."

Appendix

A. Instructional Materials Motivation Survey (IMMS [17])

(1) (or A) = not true
(2) (or B) = slightly true
(3) (or C) = moderately true
(4) (or D) = mostly true
(5) (or E) = very true

(1) When I first looked at this lesson, I had the impression that it would be easy for me.
(2) There was something interesting at the beginning of this lesson that got my attention.
(3) This material was more difficult to understand than I would like for it to be.∗
(4) After reading the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
(5) Completing the exercises in this lesson gave me a satisfying feeling of accomplishment.
(6) It is clear to me how the content of this material is related to things I already know.
(7) Many of the pages had so much information that it was hard to pick out and remember the important points.∗
(8) These materials are eye catching.
(9) There were stories, pictures or examples that showed me how this material could be important to some people.
(10) Completing this lesson successfully was important to me.
(11) The quality of the writing helped to hold my attention.
(12) This lesson is so abstract that it was hard to keep my attention on it.∗
(13) As I worked on this lesson, I was confident that I could learn the content.
(14) I enjoyed this lesson so much that I would like to know more about this topic.
(15) The pages of this lesson look dry and unappealing.∗
(16) The content of this material is relevant to my interests.
(17) The way the information is arranged on the pages helped keep my attention.
(18) There are explanations or examples of how people use the knowledge in this lesson.
(19) The exercises in this lesson were too difficult.∗
(20) This lesson has things that stimulated my curiosity.
(21) I really enjoyed studying this lesson.
(22) The amount of repetition in this lesson caused me to get bored sometimes.∗
(23) The content and style of writing in this lesson convey the impression that its content is worth knowing.
(24) I learned some things that were surprising or unexpected.
(25) After working on this lesson for awhile, I was confident that I would be able to pass a test on it.
(26) This lesson was not relevant to my needs because I already knew most of it.∗
(27) The wording of feedback after the exercises, or of other comments in this lesson, helped me feel rewarded for my effort.
(28) The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the lesson.
(29) The style of writing is boring.∗
(30) I could relate to the content of this lesson to things I have seen, done or thought about in my own life.
(31) There are so many words on each page that it is irritating.∗
(32) It felt good to successfully complete this lesson.
(33) The content of this lesson will be useful to me.
(34) I could not really understand quite a bit of the material in this lesson.∗
(35) The good organization of the content helped me be confident that I would learn this material.
(36) It was a pleasure to work on such a well-designed lesson.

∗Asterisked items should be recoded prior to data analysis (1 = 5, 2 = 4, 4 = 2, and 5 = 1).

Table 5: IMMS scoring guide [17].

Attention	Relevance	Confidence	Satisfaction
2	6	1	5
8	9	3 (reverse)	14
11	10	4	21
12 (reverse)	16	7 (reverse)	27
15 (reverse)	18	13	32
17	23	19 (reverse)	36
20	26 (reverse)	25	
22 (reverse)	30	34 (reverse)	
24	33	35	
28			
29 (reverse)			
31 (reverse)			

Table 6: IMMS reliability estimates [17].

Scale	Reliability estimate (Cronbach α)
Attention	0.89
Relevance	0.81
Confidence	0.90
Satisfaction	0.92
Total scale	0.96

B.

See Table 5.

C.

See Table 6.

D. Preusage Questionnaire

(1) When I first looked at the anatomy notes, I had the impression that studying from them would be easy for me.

(2) There was something interesting in the anatomy notes that got my attention.

(3) The anatomy notes were more difficult to understand than I would like for it to be.

(4) After reading the introductory information, I felt confident that I knew what I was supposed to learn from the anatomy notes.

(5) It is clear to me how the content of the anatomy notes is related to things I already know.

(6) Many of the notes had so much information that it was hard to pick out and remember the important points.

(7) The anatomy notes are eye-catching.

(8) Successfully learning from the anatomy notes is important to me.

(9) The quality of the writing of the anatomy notes helped to hold my attention.

(10) The anatomy notes are so abstract that it was hard to keep my attention on it.

(11) As I read through the anatomy notes, I was confident that I could learn the content.

(12) I enjoyed studying from the anatomy notes so much that I would like to know more about this topic.

(13) The pages of the anatomy notes look dry and unappealing.

(14) The content of the anatomy notes is relevant to my interests.

(15) The way that information is arranged on the pages helped keep my attention.

(16) The exercises in the anatomy notes were too difficult.

(17) The anatomy notes have things that stimulated my curiosity.

(18) I really enjoyed studying the anatomy notes.

(19) The amount of repetition in the anatomy notes caused me to get bored sometimes.

(20) The content and style of writing in the anatomy notes convey the impression that its content is worth knowing.

(21) After working on the anatomy notes for a while, I was confident that I would be able to pass a test on it.

(22) The anatomy notes were not relevant to my needs because I already knew most of it.

(23) The variety of reading passages, exercises, illustrations, etc., helped keep my attention on the anatomy notes.

(24) The style of writing of the anatomy notes is boring.

(25) I could relate the content of the anatomy notes to things I have seen, done, or thought about in my own life.

(26) There are so many words on each page of the anatomy notes that it is irritating.

(27) The content of the anatomy notes will be useful to me.

(28) I could not really understand quite a bit of the material in the anatomy notes.

(29) The good organization of the content helped me be confident that I would learn this material.

(30) It was a pleasure to work on such well-designed notes.

E. Postusage Questionnaire

(1) When I first looked at the Anatomy 4D mobile application, I had the impression that studying from it would be easy for me.

(2) There was something interesting in the Anatomy 4D mobile application that got my attention.

(3) The content of the Anatomy 4D mobile application was more difficult to understand than I would like for it to be.

(4) After downloading the Anatomy 4D mobile application, I felt confident that I knew what I was supposed to learn from the mobile application.

(5) It is clear to me how the content of the Anatomy 4D mobile application is related to things I already know.

(6) The Anatomy 4D mobile application had so much information that it was hard to pick out and remember the important points.

(7) The Anatomy 4D mobile application is eye-catching.

(8) There were stories, pictures, or examples that showed me how the information in the Anatomy 4D mobile application could be important to some people.

(9) Successfully learning from the Anatomy 4D mobile application is important to me.

(10) The quality of the content in the Anatomy 4D mobile application notes helped to hold my attention.

(11) The content in the Anatomy 4D mobile application is so abstract that it was hard to keep my attention on it.

(12) As I used the Anatomy 4D mobile application, I was confident that I could learn the content.

(13) I enjoyed studying from the Anatomy 4D mobile application so much that I would like to know more about this topic.

(14) The Anatomy 4D mobile application looks dry and unappealing.

(15) The content of the Anatomy 4D mobile application is relevant to my interests.

(16) The way that information is presented on the Anatomy 4D mobile application helped keep my attention.

(17) Using the Anatomy 4D mobile application was too difficult.

(18) The Anatomy 4D mobile application has things that stimulated my curiosity.

(19) I really enjoyed using the Anatomy 4D mobile application.

(20) The amount of repetition in the Anatomy 4D mobile application caused me to get bored sometimes.

(21) I learned some things that were surprising or unexpected from the Anatomy 4D mobile application.

(22) After working with the Anatomy 4D mobile application for a while, I was confident that I would be able to pass a test on it.

(23) The Anatomy 4D mobile application was not relevant to my needs because I already knew most of it.

(24) The content of the Anatomy 4D mobile application is boring.

(25) I could relate the content of the Anatomy 4D mobile application to things I have seen, done, or thought about in my own life.

(26) When using the Anatomy 4D mobile application, there is so much information on the screen that it is irritating.

(27) The content of the Anatomy 4D mobile application will be useful to me.

(28) I could not really understand quite a bit of the material in the Anatomy 4D mobile application.

(29) The good organization of the content on the Anatomy 4D mobile application helped me be confident that I would learn this material.

(30) It was a pleasure to work on such a well-designed mobile application.

Data Availability

The empirical data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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