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A Case Study: Evaluation of an Augmented Reality Application Developed for Biology Education

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Abstract
Virtual Reality (VR) and Augmented Reality (AR) technologies, which have rapidly developed in fields such as industry, social life, entertainment, and education, have emerged as powerful tools due to their ability to enable users to visually interact with objects. This study presents an original mobile AR application designed for biology topics including anatomy, physiology, and experimental animals, and investigates its effects on student attitudes. A mixed-methods approach was employed to assess the impact of AR technology on students' attitudes toward the course. Quantitatively, a quasi-experimental design utilizing the "AR Application Attitude Scale" and qualitatively, structured open-ended interview questions were used. The results revealed that student attitudes improved by an average of 8.35% following the implementation of the AR tools. Content analysis of student responses to open-ended questions indicated that students believed AR applications increased course interest and significantly contributed to laboratory courses.

Keywords
Augmented Reality, Virtual Reality, biology education, animal anatomy

1. Introduction

Virtual Reality (VR) and Augmented Reality (AR) technologies have rapidly evolved across numerous domains including industry, social interaction, entertainment, and education. Among these, AR stands out in education due to its ease of use on widely accessible mobile devices such as smartphones and tablets, and its capacity for visual interaction with virtual content. In the context of biology education, which plays a pivotal role in medical and veterinary training, hands-on experience under realistic conditions is essential for students to develop both knowledge and practical skills relevant to their professions. Particularly in topics involving human and animal anatomy, traditional methods such as cadaver dissection or the use of live experimental animals face ethical, financial, and logistical challenges. Therefore, incorporating innovative technologies like AR is becoming increasingly necessary.

Several prior studies have demonstrated the advantages of AR in anatomical education. Ferrer et al. developed an AR-based book incorporating magnetic resonance imaging (MRI), anatomical dissections, and illustrations, which improved student motivation, spatial understanding, and independent learning [1]. Moro et al. compared VR/AR tools with tablet-based learning in anatomy education and found immersive technologies significantly enhanced learning engagement and outcomes [2]. In another study, an AR-based MagicBook allowed students to explore neuroanatomy content flexibly and independently, reducing cognitive load [3]. Susilo et al. showed that AR fostered more effective student-object interaction and observation in biology subjects [4]. Kalana et al. highlighted how mobile AR has reshaped the traditional biology classroom by enabling dynamic and interactive learning experiences [5]. In a study examining students' attitudes towards the use of AR applications in education, it was revealed that AR applications positively affected students' attitude levels and opinions towards their use in education [6]. There is growing evidence that the integration of animations with augmented reality can enhance learners’ engagement, competence, and skill development, particularly when compared to traditional didactic methods. Furthermore, studies have shown that AR significantly improves student engagement and facilitates skill acquisition more effectively than conventional teaching approaches [7]. A needs analysis study by Arslan et al. indicated that participants have high expectations regarding the use of VR/AR technologies in vocational education and training in VET [8]. To address the high costs associated with physical workshop and laboratory setups, many researchers and institutions are developing virtual reality applications as more cost-effective and accessible alternatives. Similarly, AR is being explored as a practical and scalable solution for reducing the financial burden of physical learning environments [9].

This study introduces a mobile AR application specifically developed for biology education, including subjects such as anatomy, physiology, and experimental animals. It further investigates the application's effect on students' attitudes towards their learning experiences.

2. Material and Method

This study involves the development of an original AR application for biology education particularly for courses related to experimental animals and evaluates its impact on student attitudes through both quantitative and qualitative methods.

2.1. AR Application Development for Biology Education

Arslan Yıldız and colleagues developed an AR application to enhance teaching and learning outcomes in courses such as biology, anatomy, physiology, and experimental animals [10]. The first phase of the AR development study involved a needs analysis, which was conducted to define the scope and boundaries of the content and application. The results of this analysis informed the creation of the instructional content and scenarios, with various scenarios designed to facilitate learners' understanding of the subjects. The final phase of the study included the development, testing, and post-production of the AR application. A screenshot of the developed AR application is presented in Figure 1.

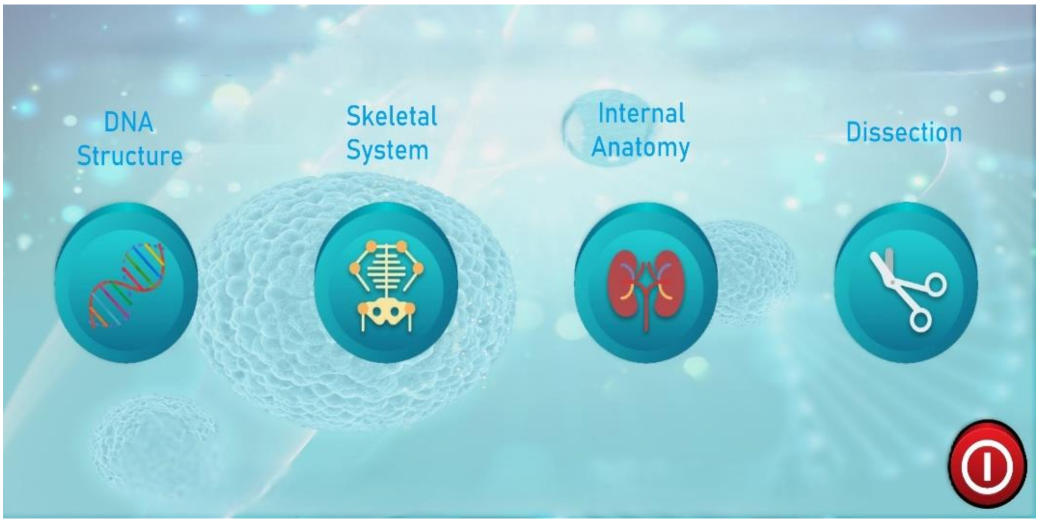

Fig. 1. Menu content of the application

AR technology involves overlaying computer-generated objects onto real-world images and presenting them to users via a computer or mobile device screen. In this study, Unity a widely used platform for AR development was employed to create interactive AR content, and ARCore was integrated to build the AR experience. The frog model, used as the experimental animal in the application, was sourced from the Unity3D asset library. The designed scenarios were animated and rendered as three-dimensional sequences in different scenes. Once the animations were completed, the ARCore plugin was integrated into Unity to enable AR functionality.

Figure 2 illustrates an AR scene demonstrating the skeletal and muscular systems. Figures 3 and 4 show how the three-dimensional models are positioned on a mobile device screen.

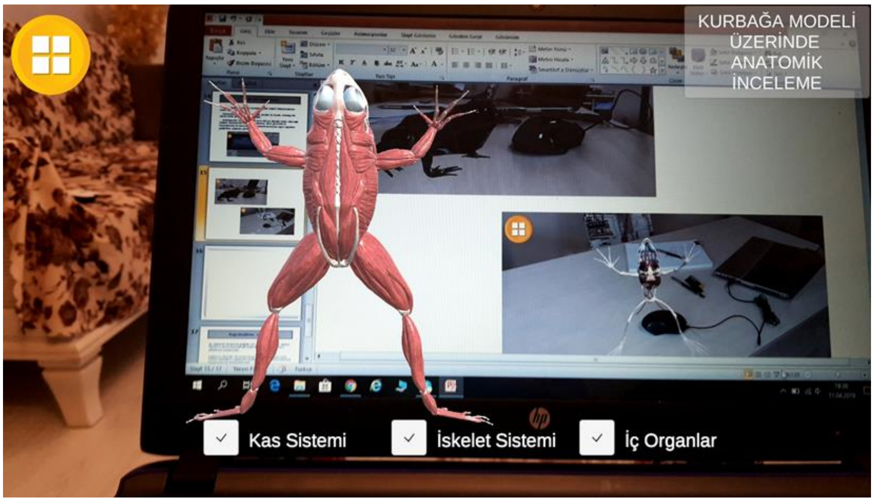

Fig. 2. Demonstration of skeletal and muscular system with AR

Fig. 3. Positioning the three-dimensional model on the mobile screen


Fig. 4. Positioning the three-dimensional frog model on screen

2.2. Assessing the Effect of AR on Student Attitudes

A mixed-methods approach was adopted to investigate the impact of AR-supported learning on students' attitudes. For the quantitative part, a quasi-experimental design was implemented using the "AR Application Attitude Scale," which was developed by the authors. The scale included three dimensions: awareness, perception, and expectation. It was administered both before and after the AR experience. The sample consisted of 20 associate degree students enrolled in the Laboratory and

Veterinary Health program at Bursa Uludağ University. A total of 13 Likert-scale questions were used to assess their attitudes. Data were analysed using Microsoft Excel. An independent-samples t-test (with a 95% confidence level) was applied to evaluate pre- and post-intervention results. The t test results are presented in Table 1.

Table 1. Independent t-test results for re and post-tests

	N	*Mean* $\bar{x}$	*St. Deviation*	*t*	*p (2-lead)*
Pre-test	20	3,46	0.69	2.024	0.105
Post-test	20	3.75	0.37		

In this section, the first three questions were designed to assess participants' awareness of the topics covered in the Experimental Animals course. The following five questions aimed to evaluate their perceptions, while the final five focused on measuring their expectations. In this approach, an increase in scores was anticipated for the awareness and expectation dimensions when comparing pre-test and post-test results. Meanwhile, the perception-related questions were intended to capture changes in participants' attitudes. As illustrated in Figure 5, the overall difference between the pre-test and post-test scores was 8.35%. When analyzing the three main categories individually, awareness showed a 13.02% increase on average. Although some individual perception items showed variation, the overall average for this category remained unchanged, yielding a net percentage change of 0%. In contrast, the expectation-related questions exhibited an average increase of 11.76%.

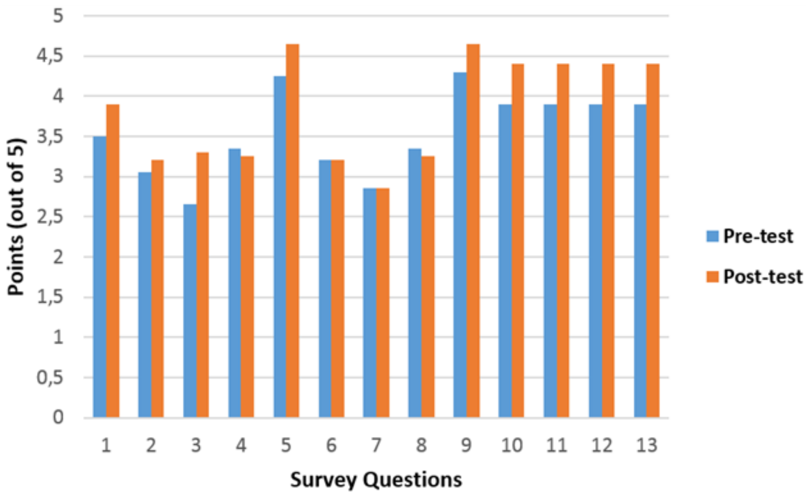

Fig. 5. Comparison of attitude scores measured before and after the AR experience

In the qualitative section, two structured open-ended interview questions were used as data collection tools for content analysis. In the first question, students were asked to share their opinions about the AR application they experienced in the Experimental Animals course. The second question prompted them to identify any areas for improvement they foresaw in the AR application.

3. Findings and Evaluation

3.1. Data Analyses

The awareness dimension of the study consisted of items designed to examine student attitudes regarding three key areas: their level of knowledge about experimental animals, the use of animals in educational settings, and the overall applicability of Augmented Reality (AR) in education. Following the AR experience, students demonstrated a 13% increase in their awareness scores—an improvement that is considered substantial. The most significant gain (15.78%) was recorded in the item assessing the usability of AR applications in educational contexts.

The perception dimension included five items. Although the overall average of this dimension remained unchanged, there were meaningful variations on an item-by-item basis. A 2.98% decrease was observed in students' agreement with the items "It is important to practice under real-life conditions in experimental animal training" and "Minor surgical interventions are more appropriately performed with real materials". This suggests a perceptual shift: after experiencing the AR application, students became more open to the idea that such procedures might be effectively simulated in virtual environments. Conversely, perception increased for items emphasizing the importance of understanding theory and practicing under real conditions, while the item advocating for the use of real materials (animals) showed no change.

The expectation dimension consisted of five items. The average increase across these items was 11.76%. The item stating, "Augmented Reality applications, which enable the visualization of objects in virtual environments, will play an important role in education" stood out with the highest individual increase at 12.82%, and it also had the highest mean score in the pre-test results—indicating that students had high expectations for AR even before the intervention.

3.2. Content Analyses

Student responses to the open-ended questions were categorized into four main themes:

- Motivation: 91.6% of students reported that the AR application improved their understanding and increased their motivation to learn.
- Knowledge and Skills: 25% of the participants stated that while the AR application supported learning, real-world practice should still accompany virtual training for optimal outcomes.
- Educational Need and Ethical Benefit: 41.6% of students believed that the use of live animals in lessons could be reduced thanks to AR technology, fulfilling educational objectives without causing harm to living beings.
- Expectations for Improvement: 83.3% recommended expanding the animal diversity and enhancing the dissection features of the application. Additionally, 66.6% suggested improvements in the software interface to make the application more user-friendly and effective.

4. Conclusion

The findings of this study suggest that students possess the intellectual, technological, and behavioural readiness to engage with virtual and augmented reality applications in educational settings. This readiness can be further reinforced through strategies that increase awareness, actively manage perceptions, and meet learners' evolving expectations. To ensure the sustainability of these positive shifts in student attitudes, it is crucial to develop VR/AR applications that are accessible across educational levels from early learning through higher education and even into lifelong learning contexts. The integration of such tools can foster more interactive, ethical, and resource-efficient learning environments. Looking ahead, it is anticipated that mixed reality platforms currently under active development will become more prominent in education. Their successful adoption will depend heavily on collaboration between educators, content developers, and software engineers. These joint efforts will be key to creating high quality, adaptable, and pedagogically sound AR/VR applications that are fully aligned with educational goals.

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