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ARnatomy: Anatomical Visualization in Mixed Reality, a New Way of Learning

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Abstract*– This paper presents an advanced tool for the study of anatomy optimizing the educational process through mixed reality technology using Virtual and Augmented Reality. This innovative approach seeks to transform medical education by offering an alternative method to traditional learning based on books and physical models. The advanced capabilities of this technology are explored, which allows the superposition of holograms in the real environment, providing an immersive and interactive experience for students. The use of Microsoft HoloLens 2 glasses enhances the teaching of human anatomy by displaying interactive 3D holograms. This solution allows teachers and students to explore anatomical models in an immersive environment, improving knowledge, understanding and retention. The development of the software is based on specialized tools such as Unity and Mixed Reality Toolkit, which facilitate the creation and manipulation of three-dimensional models of human organs with a high level of detail. In addition, the capabilities of HoloLens 2 sensors and lenses are considered to improve the accuracy and interaction with holograms, allowing users to visualize, rotate and examine anatomical structures in real time. The integration of mixed reality in the classroom provides a deeper understanding of anatomy, improving knowledge retention and student interaction with content.

Keywords—Augmented Reality, Virtual Reality, Medical Education, Engineering integration.

I. Introduction

According to Fuchs and Bishop [1] Virtual Reality (VR) can is defined as a "real-time interactive graphics with 3D models, combined with a display technology that gives the user the immersion in the model world and direct manipulation". In addition, Augmented Reality (AR) could be defined as an interactive experience that combines the real world and computer-generated 3D content. AR can use multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory [2]. By integrating a visual and interactive learning experience, this technology facilitates a deeper understanding and improves knowledge retention [3].

Over the past two decades, medical schools around the world have steadily reduced the number of laboratory contact hours. The reduction in teaching time and the prevailing pandemic in recent years have forced curriculum directors to consider new ways of teaching anatomy to medical students, precisely using MRI technology, among others [4]. Therefore, there is a need for immersive and interactive learning experiences in medical education. Despite advancements in technology, traditional methods of studying human anatomy often rely on static images, manakins, and costly equipment, which may not all be accessible to institutions and can limit the student's engagement. However, virtual reality (VR) and augmented reality (AR) displays can be used to improve the visualization of medical images, allowing for more natural interaction with the environment [5]. For example, Soulami et. Al [6] system for the reconstruction of three-dimensional brain models containing a glioblastoma tumor using the Microsoft headset HoloLens. The developed mixed-reality system projects overlap the 3D brain model from the MRI images onto the patient's head during the surgery.

This paper presents the integration of mixed reality using the Microsoft HoloLens 2 for providing an alternative learning experience in medical schools. It is worth mentioning that the system is integrated by a web application for configuration purposes and a Unity application to present the VR and AR scenarios to the students. The main idea is to use Microsoft HoloLens 2, and its mixed reality technology, to provide an alternative learning experience where students and professors can use HoloLens 2 to interact and learn the human anatomy using several scenarios. Each scenario can work as a 3D hologram of an anatomical structure. The main idea use of mixed reality can make the visualization and interaction of the human anatomy more engaging for students. The Microsoft HoloLens 2 is a mixed reality headset that offers users a seamless blend of virtual and real-world environments. With its transparent lenses and advanced sensors, this innovative headset can project virtual holograms into the user's physical surroundings, opening a world of possibilities for diverse applications. HoloLens 2 is not for entertainment and gaming necessarily but rather it is a powerful tool for learning, productivity, and collaboration. By overlaying virtual objects onto the real world, HoloLens 2 has the potential to revolutionize how we interact with information, learn complex concepts, and engage with our surroundings. From medical education to engineering simulations, the possibilities are boundless, making HoloLens 2 a compelling subject of study and exploration [7 - 9].

Additionally, this paper presents the capabilities of the Mixed reality toolkit in section II followed by a brief description of the system design in section III. Section IV

presents the actual applications. Finally, the conclusions are presented in section V.

II. System Design

This section presents a brief of methodology, structural diagram and Entity-Relationship diagram.

A. Methodology

A Kanban and Lean Startup methodology hybrid was used for the project flow management. It is a combination when there is a need for adjustment and feedback loops [10 - 11]. The workflow is divided into 5 stages: “To-Do”, “Work-in-progress”, “Test”, “Review” and “Done”.

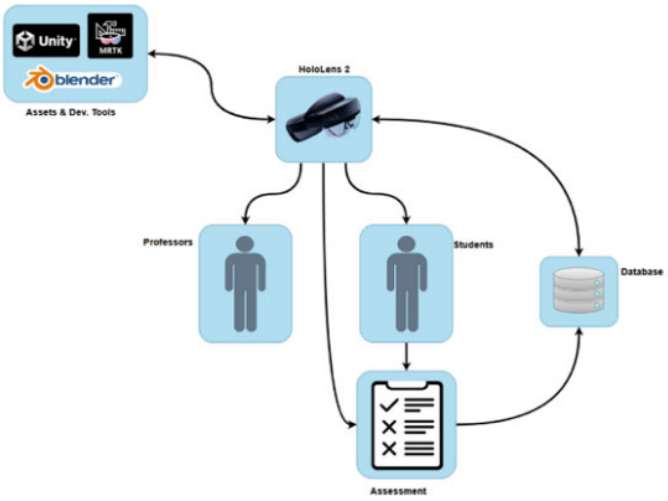

Figure 1. Structural Diagram

B. Structural Diagram

The structural diagram, Figure 1, shows the connection of the tools for development in the HoloLens 2. The AR-natomy application is integrated into the mixed reality headset. Students and profressors use the HoloLens 2 to view the various scenarios, with students have the option to take an assessment. This assessment is stored in a database for record keeping.

C. User Story Diagram

Figure 2 shows how ARnatomy interacts with the different actors: students and teachers and how different scenarios can be visualized where each one is detailed with their functions. The evaluations related to the scenarios improve the learning experience.

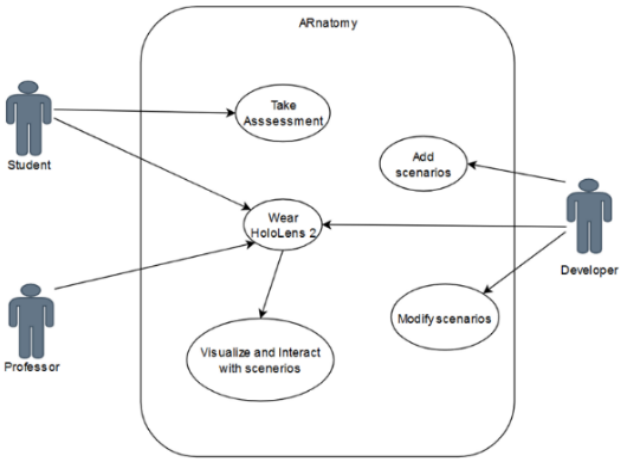

Figure 2. User Story Diagram

D. Solution Description

An innovative educational system using mixed reality through HoloLens 2 glasses was designed and implemented to optimize the teaching of human anatomy. The solution allows the visualization of interactive 3D holograms, allowing teachers and students to explore anatomical models in an immersive environment [12].

1. Functionality for Teachers
   a) Content Creation and Control: Teachers can upload detailed 3D models of organs and anatomical systems. They can also point, enlarge, or dissect structures in real time using gesture commands.
   b) Interaction with Students: Teachers can share their holographic view with the entire class. Annotations can be overlaid, and specific anatomical structures can be highlighted.
   c) Assessment and Monitoring: Teachers can generate interactive questions and assess student participation in real-time.

2. Student Functionality
   a) Individual and Interactive Exploration: Each student can examine organs 360°, zoom in, and view internal layers (muscles, blood vessels, nerves). A comparison mode can be activated that shows healthy structures versus those affected by disease.
   b) Collaborative Experience: Students can collaborate in groups to solve anatomical challenges. They can also simulate basic medical interventions, such as the study of blood circulation or lung activity.
   c) Adaptive Learning: The system can adjust the complexity of the content according to the student's level. An interactive question module with real-time feedback is included.

3. Solution Benefits
   a) Increased knowledge retention thanks to visual and tactile interaction.
   b) Immersive and risk-free learning compared to physical models or actual dissections.
   c) Optimization of teaching time by allowing autonomous and guided exploration.
   d) Remote accessibility for students who cannot attend in person.

II. Mixed Reality Toolkit

The mixed reality tool kit is an extension for unity which include all the interaction paradigms that a user would like [4] [13 - 14].

Figures 3, 4 and 5 show the different interaction paradigms and these include:

- Press Interactions: Users can select and manipulate objects with a simple press gesture.
- Touch Interactions: Objects can be touched and moved within the holographic space.
- Slider Interactions: Allows for the adjustment of parameters such as opacity or transparency of anatomical structures.
- Pinch Interactions
- Hand Mesh & Joint Visualization: Visualizes hand joints and meshes to
  provide a more realistic interaction experience.
- Direct Manipulation (One/Two Handed)
- Hand Ray for far interaction

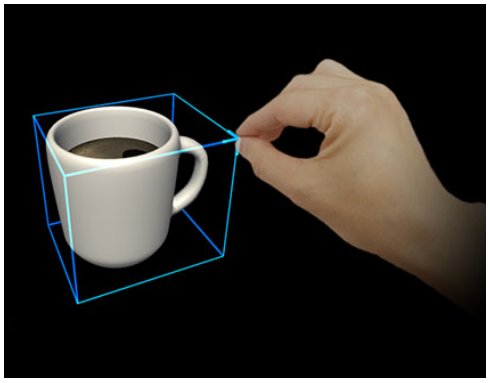

Figure 3. Pinch Interaction [14]

To develop an immersive application that can be rich in content, it is important to include 3D holographic models. To fullfill this requirement we'll be using Blender.
Blender is a popular 3D modeling program since its free and it is considered by many a professional-level tool.

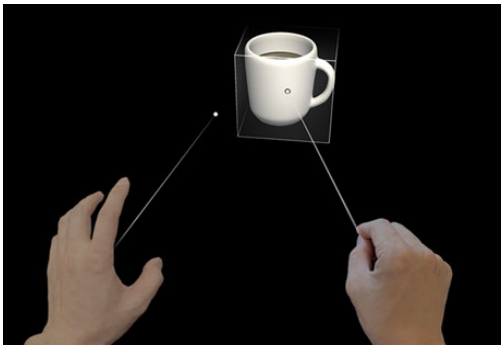

Figure 4. Hand Ray Interaction [14]

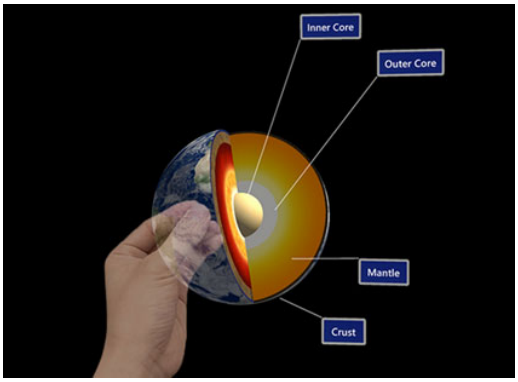

Figure 5. Object Manipulation Interaction [14]

IV. The Actual Application

Two applications were developed: a web application for register users and assesment results, and a unity application.

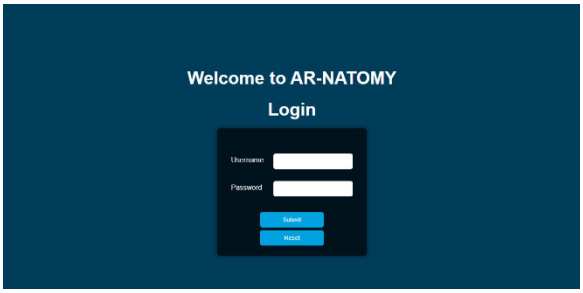

Figure 6. Login Page

A. Web application

Figure 6 shows the first page of the web application which is the Login page, here the user enters his credentials (username and password), these credentials are sent to the database and if a ResultSet is returned, we confirm that access is authorized for that user.

The web application consists of three roles such as an:

1. *Administrator:* Administrators have access to user management functions such as adding, modifying or removing users. Administrators can also view and modify grades if necessary. Administrators have the access to add users to the web application. They determine a username, full name, initial password, and the role that the user to be added will contain. After successfully adding a user, they can login and have access to any of the pages their respective role has access to. The modified user page allows administrators to modify any user account. They can modify the user's username; name and they can assign a new password. In the remove-user page, administrators select the user they want to remove, click submit, and the delete operation is executed.
2. *Instructor.* Just like administrators, instructors have access to view any student's grades and to modify them if necessary. Instructors have access to manage the visibility of each assessment on the management assessment page. When submitting the visibility status for each assessment, the web application sends the status for each assessment via JSON in a servlet that sends the JSON information to the Unity application. The Unity application then receives the status for each assessment, and based on each status it displays or hides the button for each assessment in the Assessments menu.
3. *Students* can see all their grades when they access the view my grades page via the welcome menu page. This is the only function students have access to in the web application.

B. Application in Unity

VR and AR applications provide some examples of how scientists and engineers can use advanced visualization technologies to perform data analysis and evaluation, thereby transforming scientific discovery [15]. Therefore, an application was developed using Unity. The application allows Instructors and Students to enter by logging in as shown in figure 7.

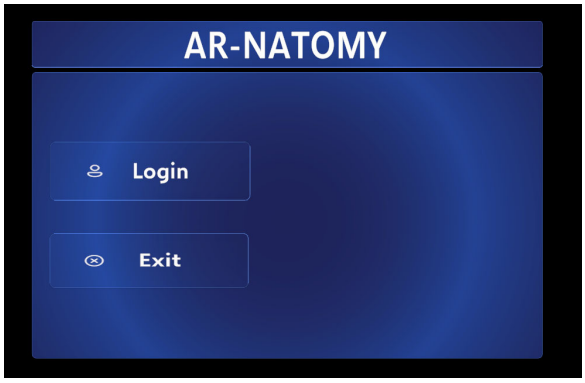

Figure 7. Startup menu

Once users launch the ARNATOMY application, they are presented with a simple start menu with options to log in or log out of the application as shown in figure 8. ARNATOMY is designed to allow only existing users to log into the application.

The Login button in Figure 8 lets the user in separate scene that handles the log in logic developed with C# scripting. The user needs to have an existing account to log in successfully in the application.

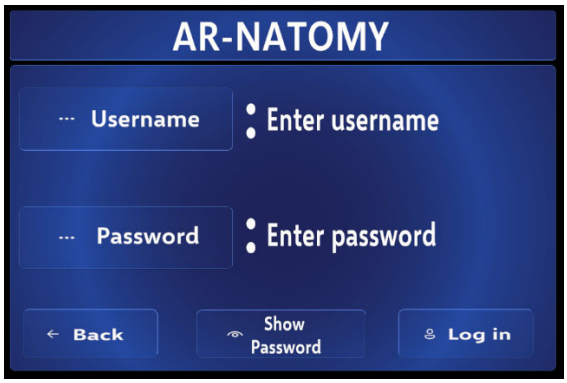

Figure 8. Log in menu

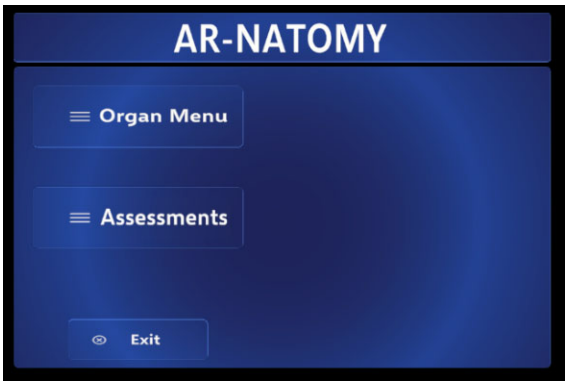

Figure 9. Main Menu

The main menu interface in Figure 9 shows the options to enter the Organs Menu and the Assessments menu which is only available to users with the student role.

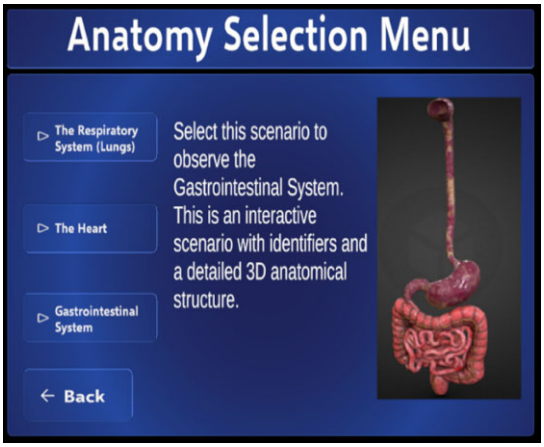

Figure 10. Anatomy Selection Menu

The anatomy selection menu in Figure 10 lets the user select one of the three scenarios available:

- The Heart (Cardiovascular System), Figures 11 and 12
- Gastrointestinal System, Figure 13
- The Respiratory System, Figure 14

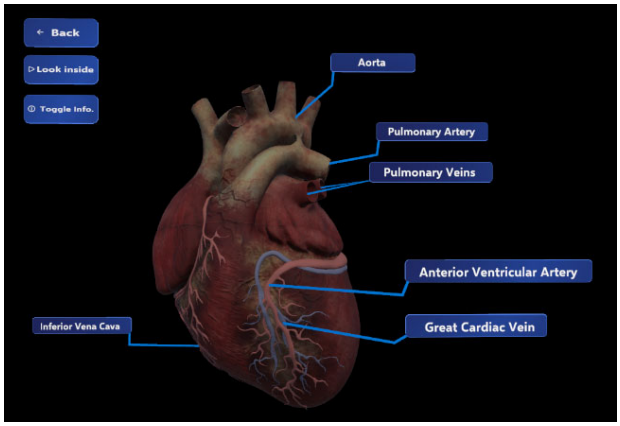

Figure 11. Cardiovascular System Scenario

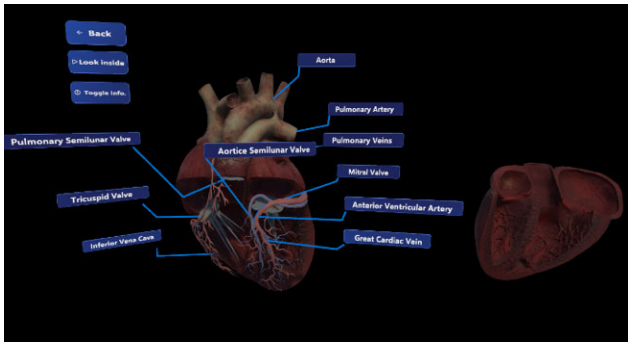

Figure 12. Cardiovascular System Scenario (Animation)

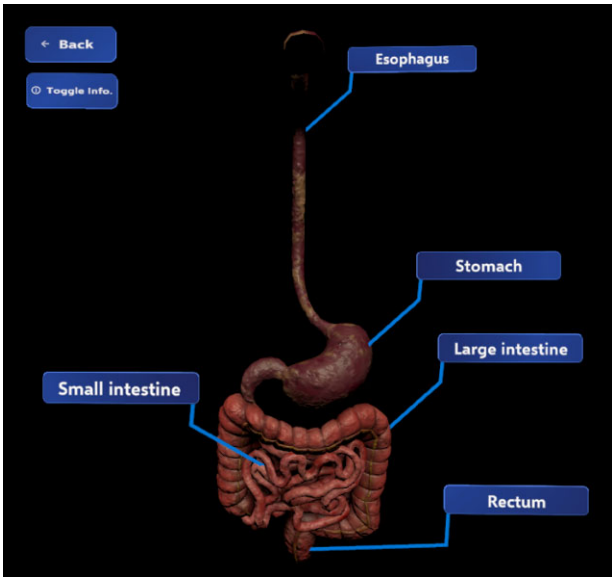

Figure 13. Gastrointestinal System Scenario

In addition, when a user selects an anatomical scene to view, it will seamlessly transition to a scene with the anatomical structure present with identifiers to help better understand the anatomical structure as shown in figure 14.

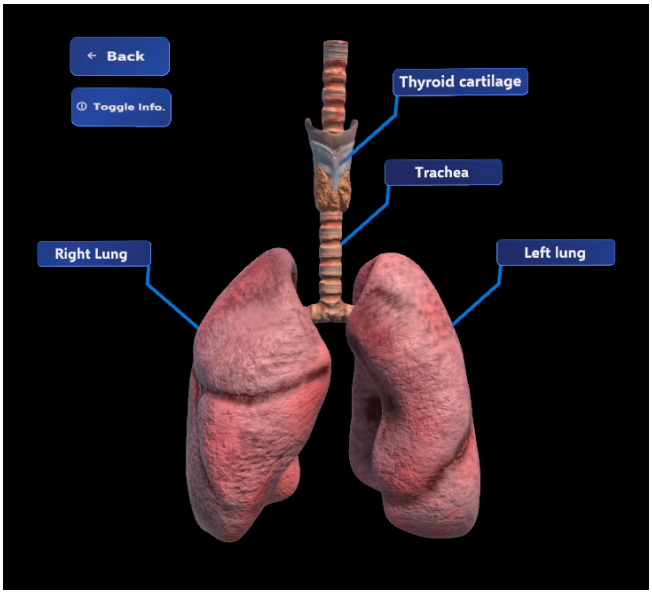

Figure 14. The Respiratory System Scenario

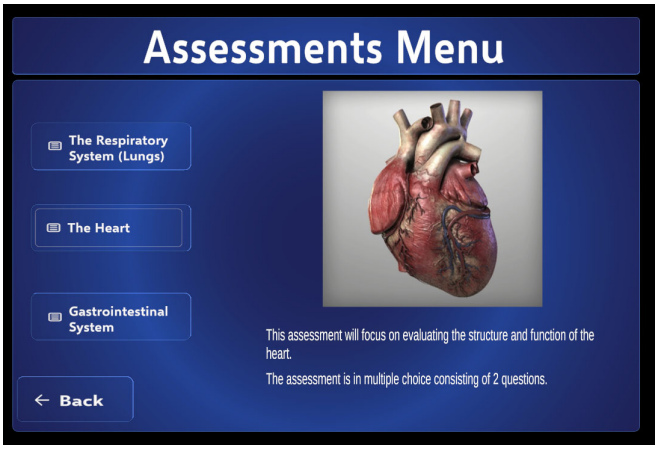

Figure 15. Assessment Menu

ARNATOMY allows students users to take assessments based on the anatomy scenarios that are present in ARNATOMY as shown in Figure 15. This menu is unique in that it verifies which assessments are available to take. Using the web application, the instructor determines which assessments are available which are reflected in the unity application. Additionally, Figure 16 shows an example of the assessment tool for students. Once the students complete the assessment, they are presented with a scenario containing the assessment results, which are then uploaded to the ARNATOMY database as shown in figure 17.

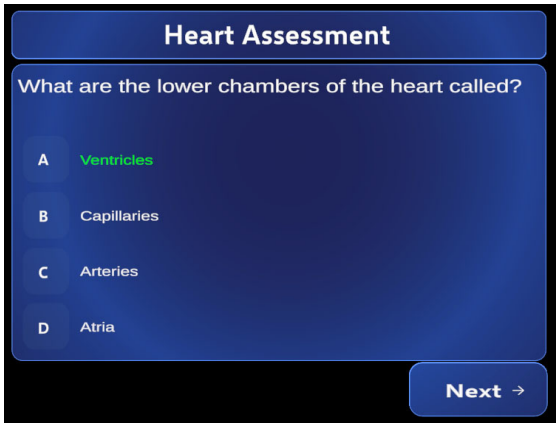

Figure 16. Assessment Scenario

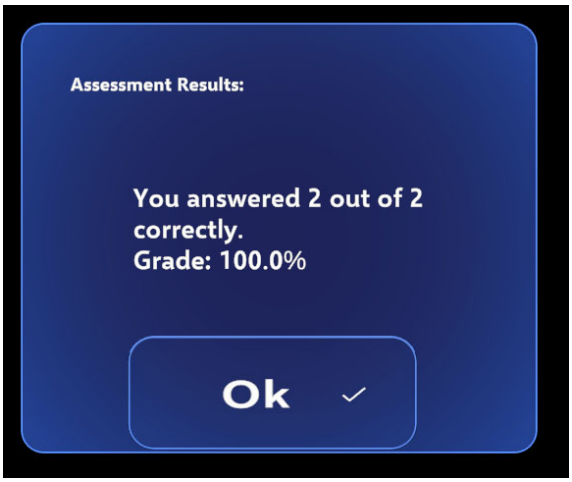

Figure 17. Assessment Results Scenario

V. Conclusions

The ARNATOMY application has been successfully implemented with three interactive models: the heart, respiratory system, and gastrointestinal system. These models provide an enhanced visualization of anatomical structures, enabling a more intuitive and comprehensive understanding for students. Furthermore, a complementary web application has been developed, offering user management capabilities, assessment accessibility, and integration with the Unity app for seamless functionality. This web application also facilitates grade viewing and modification, ensuring an efficient and cohesive system for educators and learners alike.

Through a robust conceptual framework utilizing methodologies like Kanban and Lean Startup, structural and user story diagrams, and entity relationship diagrams, we have mapped out and realized a clear path for the development and integration of the ARNATOMY application into academic settings. Key considerations for performance, scalability, maintainability, and compatibility have guided this process, ensuring that the application is well-positioned to evolve alongside educational needs and technological advancements.

The integration of AR and VR into educational environments offers significant potential for improving learning outcomes, especially in fields like medical education were complex anatomical structures benefit from enhanced visualization. With the added functionality of the web application, the ARNATOMY project demonstrates how technology can bridge traditional and modern learning tools, creating a future where education is increasingly engaging, accessible, and impactful. This success underscores the limitless possibilities for immersive and interactive learning, paving the way for broader adoption of mixed reality in education.

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