Faculty of Computer Science and Information Technology

PathoSphere Enhanced Learning through VR Gamification

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DECLARATION

I hereby declare that this project is none other than my work, with the exception of the references and other sources found within this work, on witch have been stated.

ACKNOWLEDGEMENT

I would like to express my gratitude to Dr. Suriati Khartini binti Jali for being my supervisor and guiding me for this whole Final Year Project. She gave me an opportunity to tackle a project that contributes to new generation of technology. I would also like to give my special thanks to the Unimas Anatomy and Pathology Museum, for their support and resources. Lastly, I am also deeply thankful to the survey participants for their insights, which helped for the development of this VR gamification system and to my family, friends and colleagues for their encouragement and support.

ABSTRACT

This project focuses on enhancing educational engagement through the development of a gamified Virtual Reality (VR) experience, PathoSphere, designed for the UNIMAS Anatomy and Pathology Museum. PathoSphere integrates game mechanics, such as interactive challenges, real time feedback and achievement system, to create an immersive and interactive learning environment. The system enables users to explore anatomical models, solve quizzes and engage in surgical simulations, all tailored to foster critical thinking and practical knowledge. Using the Agile methodology, the project followed iterative phases, including planning, designing, development, testing and release. The design prioritizes user-friendly navigation, personalized difficulty levels and interactive elements to ensure accessibility and engagement for diverse learners. Tools such as Unity and Blender were employed to develop the VR environment, optimized for use with Pico 4 hardware. By addressing limitations in traditional static VR systems, PathoSphere offers an innovative approach to STEM education, transforming complex medical concepts into manageable, gamified tasks. This project contributes to the field of educational technology by presenting a dynamic and adaptable VR solution for anatomy and pathology education, enhancing knowledge retention and learner motivation.

ABSTRAK

Projek ini memfokuskan kepada cara meningkatkan penglibatan pendidikan melalui Realiti Maya (VR) yang digamifikasi, PathoSphere, iaitu nama bagi VR yang direka untuk Muzium Anatomi dan Patologi UNIMAS. PathoSphere menggunakan mekanik permainan, seperti cabaran interaktif, maklum balas pada waktu yang sama, dan sistem pencapaian, untuk mencipta ruang pembelajaran yang mendalam dan interaktif. Sistem ini membolehkan pengguna meneroka model anatomi, menyelesaikan kuiz, dan menglibatkan diri dalam simulasi pembedahan. Elemen-elemen ini disesuaikan untuk memupuk pemikiran kritis dan pengetahuan praktikal. Dengan menggunakan metodologi Agile, projek ini mengikuti fasa iteratif, termasuk perancangan, reka bentuk, pembangunan, pengujian, dan pelepasan. Reka bentuk mengutamakan navigasi mesra pengguna, tahap kesukaran yang boleh ubah, dan elemen interaktif untuk memastikan aksesibiliti dan penglibatan bagi pelbagai pelajar. Perisian seperti Unity dan Blender digunakan untuk membangunkan persekitaran VR, disesuaikan untuk digunakan dengan perkakasan Pico 4. Dengan menangani cabaran dalam sistem VR statik tradisional, PathoSphere menawarkan pendekatan inovatif kepada pendidikan STEM, mengubah konsep perubatan yang kompleks menjadi tugas yang mudah difahami dan digamifikasi. Projek ini menyumbang kepada bidang teknologi pendidikan dengan mempersembahkan penyelesaian VR yang dinamik dan boleh disesuaikan untuk pendidikan anatomi dan patologi, meningkatkan pengekalan pengetahuan dan motivasi pelajar.

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Chapter 1 : Introduction

1.1 Introduction

The combination of virtual reality (VR) with gamification has changed how people engage with digital surroundings and opened up new possibilities for immersive experiences. Gamification itself is the application of game design elements in non-game activities (Khaldi et al., 2023). By integrating elements such as interactive challenges, feedback loops and reward systems, VR environments offer users a more immersive and dynamic way to interact with content. These elements are particularly useful in educational settings, where they can transform traditional learning into gamified active exploration. Game mechanics such as spatial navigation, game progression and information gathering ensure that users are not only engaged but also challenged at a level appropriate to their skills. In VR, this leads to a deeper understanding of complex topics which is human anatomy and pathology through interactive and personalised learning experiences.

This project centers on the creation of a gamified experience within PathoSphere, which is a Virtual Reality Space of the UNIMAS Anatomy and Pathology Museum. The aim is to enhance the educational impact by integrating game mechanics that promote interactive learning. By transforming the exploration of human anatomy and pathology into a series of engaging challenges and activities, the project seeks to motivate users to actively engage in learning, especially students with related fields.

The game design focuses on incorporating elements such as problem-solving tasks, achievement systems and progression-based rewards. Users will embark on immersive journeys through virtual anatomical environments, where they must complete various tasks related to organ functions and diseases. Challenges such as identifying organs, recognising medical terminology and visualising basic surgical procedures will encourage critical thinking and practical application of knowledge. Additionally, interactive feedback systems will keep users engaged while ensuring a suited learning experience for different skill levels after feedback.

This project will outline the core gamification principles and the mechanics employed as well as how these two components are expected to enhance the educational value of PathoSphere.

1.2 Problem Statement

Different active learning techniques including practical based are increasing nowadays (Oje et al., 2024). This is due to interactivity, which promotes deeper engagement and understanding by allowing students to experiment, observe and apply concepts in real time. Advantage of hands-on experimentation or practical learning is that it gives students active learning opportunities in order to learn concepts that are relevant (Liu & Fang, 2021). This is especially true in the sense of students seeing the relevance of STEM concepts in real-world problems, making the subject matter not only more relatable but also more motivating. Without opportunities to engage hands-on, students may find it challenging to connect abstract ideas with practical applications, which can result in losing interest and lower retention of information.

Additionally, a lot of teaching resources nowadays are mainly static and provide little interaction, which can fail to engage students. It can be difficult for educators to effectively explain complicated terms using traditional method with texts and 2D illustrations (Qorbani et al., 2024). While there were many VR systems present currently, it lack interactivity which limits the usability, offering less experiences and hindering the potential for it to be used widespread (Grinyer & Teather, 2023). By not using the full interactive potential of VR, these systems miss opportunities to create dynamic, memorable learning environments that appeal to students' curiosity. Consequently, static VR content may not fully utilize the benefits of immersion and can feel similar to traditional, passive forms of learning, leading to a lack of engagement.

Furthermore, STEM education's traditional VR learning experiences frequently do not accommodate different students' learning preferences and speeds. Every person has distinct preferred methods for organizing, perceiving and retaining information (Horvath, 2020). If the material is not interesting enough, some students may lose interest, while others who require more time to understand complicated ideas may feel hurried if personalisation is not offered. A one-size-fits-all approach can be particularly limiting in subjects like anatomy and pathology, where the complexity of content varies greatly. Without customisable levels of difficulty, students may struggle to reach their full potential, as they are not given the freedom to explore at their own pace or revisit challenging material. This lack of adaptability in VR-based learning environments can create a rigid structure, which may not fully support diverse learning styles, ultimately impacting knowledge retention and overall educational outcomes.

1.3 Objectives

- To analyse the problem with traditional VR and identify key areas where gamification can enhance the user experience within the PathoSphere VR experience using survey.

- To develop game mechanics inside PathoSphere using game elements such as interactive challenges, feedback loops and reward systems

- To validate the compatibility of the gamification inside PathoSphere with Pico 4 hardware.

1.4 Brief Methodology

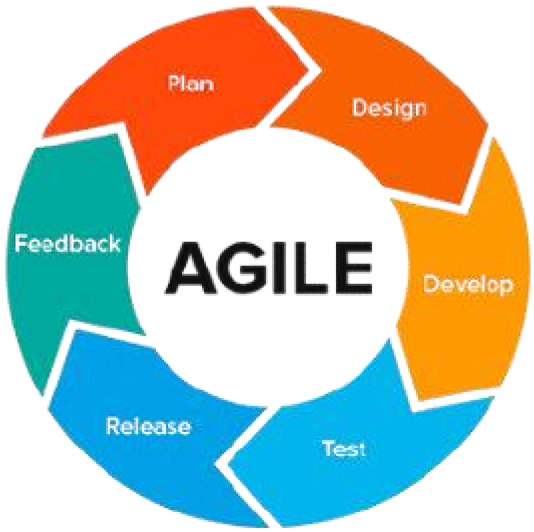

Figure 1.1 : Agile Methodology Model

In this project, the Agile methodology is employed to develop a gamified, user-centered experience for the UNIMAS Anatomy and Pathology Museum VR space. Agile's iterative approach allows for flexibility, enabling ongoing feedback and improvements and is divided into six different phases which is shown in Figure 1.1 (Oclarit et al., 2024).

Plan

The initial phase focuses on planning which includes research and analysis to identify issues in traditional non-gamified VR systems, such as limited engagement and interactivity and to determine specific requirements for an enhanced learning experience.

Design

The designing phase uses a repeating cycle to design gamification aspects which are the game elements and mechanics such as achievements, interactive tasks and feedback systems that address these issues and make learning more immersive and effective.

Develop

In the developing phase, each cycle of development incorporates the aspects mentioned previously into the VR environment, ensuring they function correctly and align with educational goals.

Testing

For the testing phase, after the prototype of the system has been developed, the initial test for the first iteration or cycle will take place using VR equipment which is the Pico 4. After that, several other iterations followed by more tests will be conducted to ensure compatibility and a seamless experience with each iteration improves the previous one.

Release

When all the other phases before this are done, the product will be released to a small-scale audience. The first release will serve as a reference for other upcoming iterations just in case the launch is unsatisfying. Several improvements will be made if that is the case. This will not continue after the project is done and the system is deemed satisfactory

Feedback

Finally, the review and reflect in feedback phases gather user feedback and refine the experience, ensuring the VR system meets its goals for engagement, usability and learning outcomes. Agile's responsive cycle ensures the VR experience remains functional and continuously improved for educational value.

1.5 Scope

The scope of this project is to develop a gamification design for PathoSphere, designed specifically for medical university students or visitors with minimal medical knowledge. The primary focus is on gamification elements that enhance interactivity and engagement, making complex anatomical and pathological concepts accessible and enjoyable to learn. The VR experience will feature essential functionalities such as interactive 3D models of human organs, disease simulations and educational challenges that guide students through foundational knowledge in an intuitive and approachable manner. Each feature is crafted with a user-friendly interface, enabling easy navigation and fostering a self-paced learning environment.

Gamified elements, such as quizzes, challenges and reward systems, will be visually clear and engaging, catering to various learning paces and interests. Educational content is curated to be simple and relatable, incorporating visual aids and layered information to enhance understanding. Existing gamification algorithms will be integrated to personalise learning experiences, ensuring that students can explore progressively challenging tasks. Beyond individual features, the ultimate goal is to deliver a comprehensive, student-centered digital tool that demystifies anatomy and pathology concepts while fostering engagement, curiosity and a deeper appreciation for medical science within a thoughtfully designed VR environment.

1.6 Significant of Project

The development of an interactive VR gamification experience for PathoSphere holds substantial significance in enhancing educational engagement for students and visitors with minimal medical knowledge. This project has the potential to transform the display-based VR experience into interactive game-like elements, effectively overcoming barriers posed by semi-dynamic displays and limited access to specimens. By prioritising a gamified approach tailored to beginner-level understanding, the project aims to make complex medical concepts approachable and enjoyable, empowering students to learn through hands-on exploration and interactive challenges.

The focus on a user-centric design ensures that educational content is presented in a simple, intuitive manner, accommodating the diverse backgrounds and knowledge levels of students. This approach is not only a design strategy but a critical factor in fostering curiosity and supporting deeper understanding among participants. By addressing the learning needs of students with minimal prior exposure to medical topics, the VR experience supports a more inclusive and engaging learning environment. Moreover, the project's adaptability for different content updates and gamification features promises a sustainable tool for future learning, capable of evolving with educational needs and advancements. Ultimately, this gamification serves as a first step in reimagining anatomical and pathological education for a VR space starting with UNIMAS.

1.7 Project Schedule

The project is expected to be completed within two semesters following the course Final Year Project I and II in Gantt Chart located in Appendix A and as shown in Figure 1.2 below:

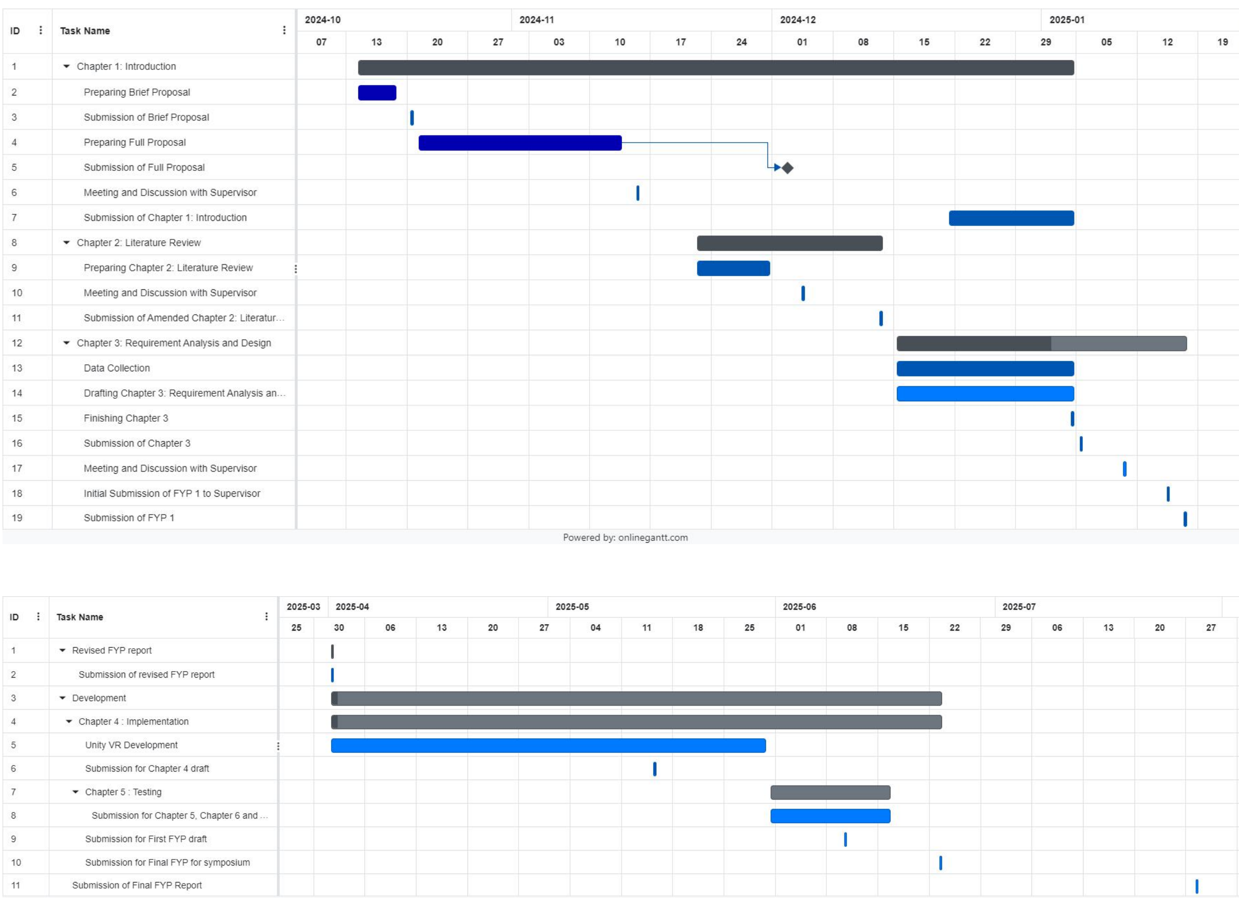

Figure 1.2: Gantt Chart for Final Year Project 1 and 2

1.8 Expected Outcomes

1. A fully functional VR system with gamification features will be developed to make learning more engaging.
2. Users, especially medical students will have practical knowledge that can be applied in real life.
3. The system will include self-assessment tools so users can improve their area of understanding after making a self-evaluation.

Chapter 2 : Literature Review

2.1 Introduction

Virtual Reality (VR) is a type of immersive technology that is similar and related to Augmented Reality (AR), which involves users to experience digital and physical environments in an immersive way using advanced hardware and software to blend reality and virtual environments (Auda et al., 2023). This is related alongside Mixed Reality (MR) and Extended Reality (XR). Specifically, it is a technology that immerses users in a whole new digital world, offering an interactive experience via glasses or headsets that lets users experience incredibly realistic representations of actual or fictional places (Al-ansi et al., 2023). According to Stendal & Bernabe (2024), being immersive means that individuals wearing head-mounted technology will use several senses, such as vision and hearing. A dynamic interaction between the potential of VR and the obstacles to its implementation describes what the study is about from scholars (Fares et al., 2024). One of the challenge in current VR is the realism on which the user can identify the difference between real life and virtual object making it less immersive (Reddy, 2023). AR however brings together virtual elements such as texts, videos, images and many more into the real world and displays it through a device screen (Yunqiamg Chen et al., 2019). The combination of digital content with real world can improve users' efficiency by making information and data available instantly (Liang et al., 2024). In the context of clinical application, AR can be used to add digital data on top of the standart clinical data (Monterubbianesi et al., 2022). In education, using AR will result in positive outcomes since it helps students to comprehend complex concepts (Mbonye & Ebrahim, 2022). The progression of these two technologies creates another technology called Mixed Reality (MR). MR is another type of reality simulator that combines AR and VR and this can be seen with Microsoft HoloLens which shows 3D projection in real life through the device lens (Aruanno and Garzotto, 2019). The potential for MR to be used in learning activities is high with many case studies conducted in literature use case (Hensen, 2023). However, there are many challenges present in implementing MR and one of it is sensory accuracy as well that presents in the interface design (Ravichandran & Nam, 2024). Finally, Extended Reality (XR) is a combination of every interactive technology previously mentioned and can be described as all virtual and real-world settings that blend computer-generated and human input to produce an interactive space (Morimoto et al., 2022). It encompasses every immersive technology and it is improving over time as well as making a great impact in education in terms of understanding syllables (Rodríguez, 2022). XR has a potential to make another accessibility options since it can be used to modify user experience based on their demands and needs (De Luca et al., 2023).

In this chapter, the literature review consists of various features and examples that are similar to this project and related to the gamification of Virtual Reality (VR) systems, specifically focusing on enhancing learning experiences within the PathoSphere VR space. Additionally, a comparison of the existing applications and this project is made to show the key differences between the applications. The chapter concludes with a summary of the key findings from the literature review, identifying gaps in existing VR systems and opportunities for innovation. These findings provide a foundation for the later chapters, guiding the development of a gamified VR system that aims to make learning anatomy and pathology engaging, accessible and effective for students with minimal medical background.

2.2 Review on Existing Games

2.2.1 InMind VR

InMind VR (Luden.io, 2015) is an educational VR game that takes players on a microscopic journey through the human brain. The game focuses on exploring neurons and identifying those associated with mental disorders. Players are placed inside a virtual brain and use their gaze to "tag" malfunctioning neurons as they travel through the neural pathways. The combination of interactive mechanics and educational content provides an engaging way to learn about the brain's structure and functions. This can be a reference for this project by showcasing how users can detect anatomy problems through immersive, interactive gameplay with eye coordination. InMind VR's use of highlighted objectives and task-focused gameplay could inspire similar mechanics in PathoSphere, such as allowing users to identify simple visual cues for diseased organs or structures while learning in a gamified environment. The interaction can be a simple point-and-click for "tagging" the objective instead of purely using eye-tracking instead. Figure 2.2 and 2.3 below show the cursor movement using purely the user's eye.

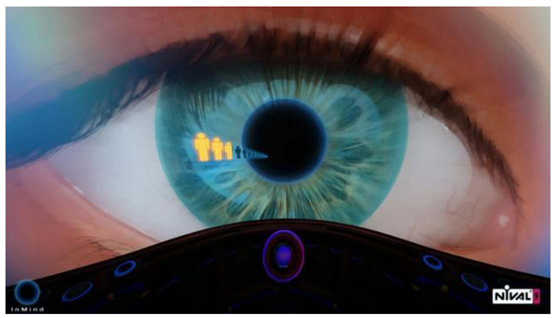

Figure 2.1: InMind VR intro screen (Luden.io, 2015)

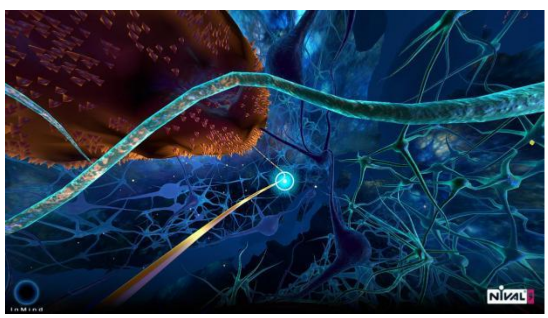

Figure 2.2: Neuron without a problem (Luden.io, 2015)

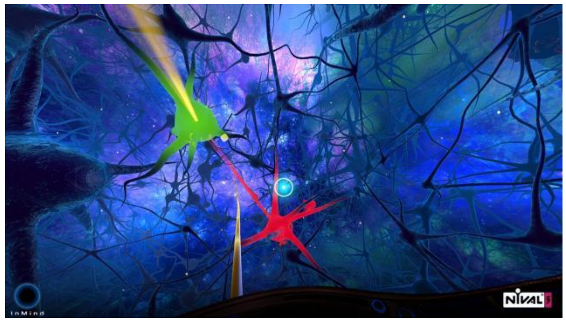

Figure 2.3: Eye detection for neurons with problems (Luden.io, 2015)

2.2.2 InCell VR

InCell VR (Luden.io, 2015) blends education and action, taking players into the microscopic world of human cells. The game is set within a futuristic biological simulation where players must protect a cell from viral attacks. It combines strategy, racing and countdown mechanics, requiring users to navigate cellular pathways while learning about cell locations inside the body. Colorful visuals and fast-paced gameplay create an eye-catching gaming experience although the faster pace it is the less likely for users to catch up fully with the educational information. This game is highly relevant to this project as it integrates the timing mechanic which is the countdown while being a navigation and racing game. Similar to InCell VR, this project can incorporate simple navigation mechanics and problem-solving tasks with countdown or time attacks to increase the difficulty and give the users more challenges.

Figure 2.4: InCell VR gameplay (Luden.io, 2015)

2.2.3 Surgeon Simulator 2 VR

Surgeon Simulator 2 VR (Bossa Studios, 2020) is an exaggerated take on performing surgical procedures. In this game, players take on the role of a surgeon and complete medical tasks, such as heart transplants or brain surgeries, using VR controllers to interact with surgical tools and patient anatomy. The downside of this game is the lack of clear instruction and guidance for completing tasks making it less viable to be an education tool. However, the game's aspect of object-oriented interaction where users directly manipulate tools and anatomy shows the potential for hands-on learning in VR and can be directly linked to the project's goal of gamifying the VR experience in PathoSphere. By integrating object-oriented tasks like manipulating organs and surgical instruments or simple simulation surgery procedures, PathoSphere could provide a more engaging way for students to learn about anatomy and pathology while fostering critical thinking and practical skills.

Figure 2.5: Surgeon Simulator 2 VR Gameplay (Bossa Studios, 2020)

2.2.4 Communicating Engineering Heritage Through Immersive Technology: A VR Framework for Enhancing Users' Interpretation Process in Virtual Immersive Environments

This research contains a gamified VR system designed to enhance user engagement and provide educational content about engineering heritage in museums (Alatrash et al., 2023). It features three modes which are an immersive exploration scenario, a narrated storytelling experience and a gamified experience with interactive tasks like puzzles and point collection. The gamified mode introduces interactive elements that make the learning process more engaging. One of the elements, navigation, is a key feature allowing users to explore and move through the virtual environment as part of both the immersive and gamified scenarios. Additionally, problem-solving tasks which require users to engage in puzzles and challenges that engage in critical thinking and active learning. The system also includes object-oriented interaction, where users interact with virtual objects to complete tasks, creating a more engaging and hands-on experience. These elements work together to create a dynamic learning environment suited to the educational content presented in the VR system and can be used in PathoSphere gamification.

Figure 2.6: Object-oriented interaction (Alatrash et al., 2023)

Figure 2.7: Tutorial stage (Alatrash et al., 2023)

2.2.5 3D Virtual Reality Game for Google Cardboard

The 3D virtual reality kite-flying game developed for Google Cardboard (Payandenick, 2017) provides an interactive and immersive experience that blends traditional gameplay with modern VR technology. Players can select from six kite types and explore three unique environments which are urban, wasteland and grassland with each of it is designed to mimic real-world conditions. The game features intuitive controls, allowing players to use head tracking for navigation and interaction, creating a smooth and engaging gameplay experience. Gamification elements such as a high-score tracking system, dynamic environmental interactions and customizable kite options enhance player engagement and replayability. Although lacking educational content, the interaction between the object and human can be used as a reference in PathoSphere VR.

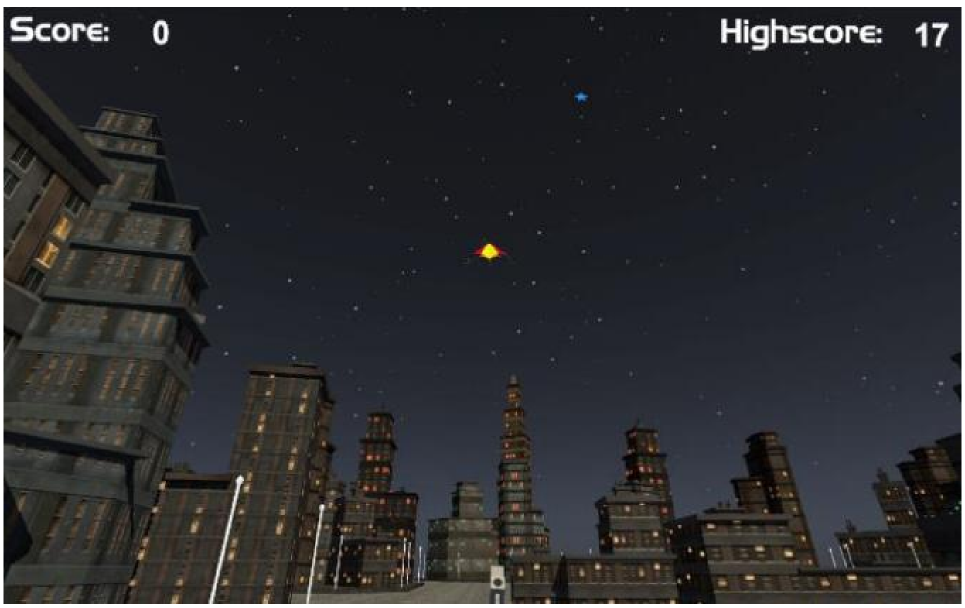

Figure 2.8: Gameplay for flying the kite (Payandenick, 2017)

2.3 Comparison on Existing Games and the Proposed Gamification for PatoSphere

Table 2.1: Comparison Table of Existing Games and the Proposed Gamification for PatoSphere

Features	Educational Information	Time-based mechanic	Navigation	Problem-solving task	Object-oriented interaction
InMindVR	Sufficient	✗	✗	✓	✗
InCell VR	Sufficient	✓	✓	✗	✗
Surgeon Simulator 2 VR	Minimal	✗	✗	✓	✓
Heritage Musem VR	Sufficient	✗	✓	✓	✓
3D Virtual Kite-flying game	Minimal	✗	✓	✗	✓
PathoSphere	Numerous	✓	✓	✓	✓

2.4 Brief Overview

"PathoSphere Enhanced Learning through VR Gamification" is designed to change anatomy and pathology education from traditional static VR space into an immersive and interactive gamified experience. The project places users, especially medical students, in a virtual environment where they explore human anatomy and pathology through gamified challenges. Players engage in tasks such as diagnosing diseases, identifying organs and solving interactive puzzles, all designed to teach medical concepts in a hands-on way. Unlike static VR experiences, PathoSphere integrates game mechanics like countdown timer, navigation, rewards, real-time feedback and adaptive difficulty, with elements such as problem-solving tasks and object-oriented interaction, combining education with entertainment. With a focus on accessibility and engagement, this project improves learning for students through a dynamic and visually compelling virtual space, making complex medical concepts more approachable and memorable.

2.5 Summary

Each of the games has gamification aspects that can be used as a reference for this project. Time-based mechanic, navigation, problem-solving tasks and object-oriented interaction are being used in this project development with education being the focus and each of the existing games did not have the combination of all which makes PathoSphere more reliable in providing educational content while being entertaining. It connects entertainment and teaching by incorporating these various gamification aspects, making difficult subjects like anatomy and pathology more interesting and understandable. This approach not only enhances user engagement but also ensures that students gain practical knowledge and retain information more effectively as oppose to the static VR experience.

Chapter 3 : Requirement Analysis and Design

3.1 Introduction

This chapter describes the requirements and design process for the gamified VR experience in the PathoSphere project. The focus is on creating an immersive educational tool for the UNIMAS Anatomy and Pathology Museum. The system is designed to engage users through interactive 3D content, gamified elements and personalized learning experiences. The Agile methodology guides the development process, ensuring user feedback is integrated to refine the system.

3.2 Agile Methodology

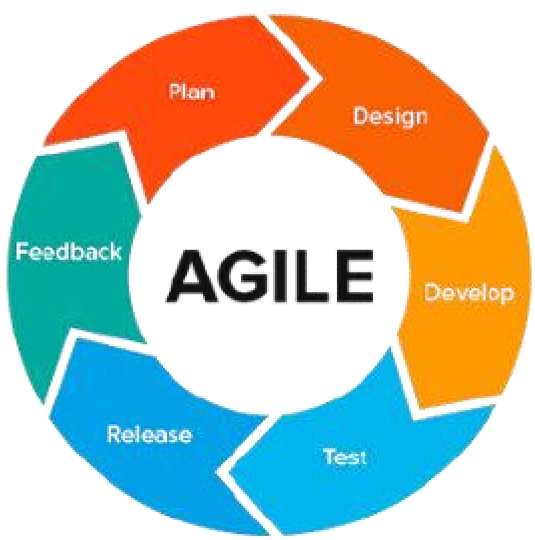

Figure 3.1: Agile Methodology Model

The Agile methodology is used in this project for its iterative and user-centered approach. The methodology is divided into several phases: planning, designing, developing, testing and refining according to Oclarit (2024). These phases ensure the system evolves based on feedback and user needs.

3.2.1 Planning

The planning phase focused on establishing the objectives and scope of the PathoSphere VR system. This includes determining the key goals, user engagement planning, gamified elements that need to be included and how to integrate them and step by step plan to develop an educationally focused VR platform. Initial sessions concentrated on defining core features such as interactive 3D anatomical models, problem-solving tasks and real-time feedback mechanisms, ensuring alignment with educational requirements and user expectations.

A detailed project timeline was established, breaking the development process into manageable stages. Resource allocation for tools like Unity and Visual Studio Code was also finalized. Additionally, planning included identifying which targeted group of users to focus on, such as students, educators, or technical experts to ensure their needs and expectations would guide the design and development process. Clear milestones and deliverable were set to track progress throughout the project lifecycle.

3.2.1.1 Survey

A survey was conducted to further study the users, which are students. There are three section of the survey that the users needed to answer. Section one is about User's Background and Needs, section two is Preferences for Gamification Features and the last section is Interaction and Accessibility of the VR gamification product. There are 45 participants that accepted and agreed with the terms and condition of the survey.

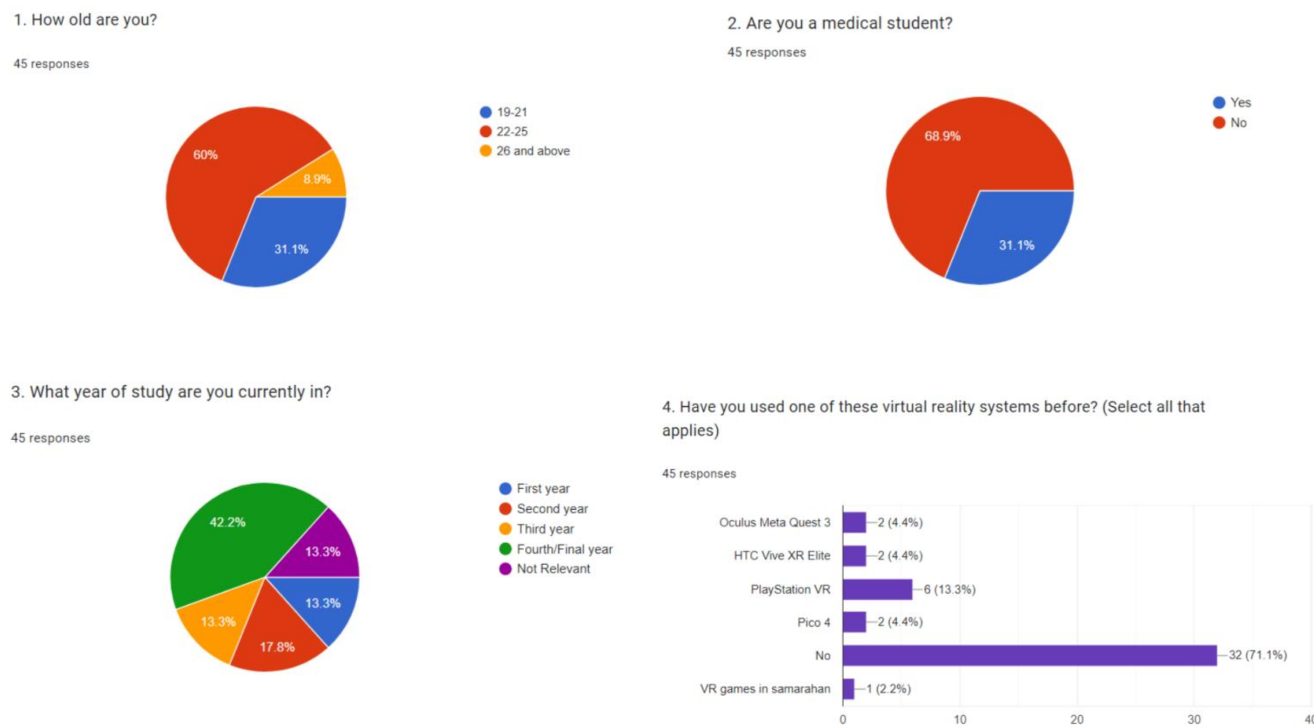

Figure 3.2: The demographic of the survey participants

The first graph represents the age distribution of 45 respondents, showing that the majority (60%) are aged 22-25, followed by 31.1% in the 19-21 range and a small portion (8.9%) aged 26 and above. The second graph indicates that most respondents (68.9%) are not medical students, while only 31.1% are. The third graph categorizes respondents by their year of study, with the largest group (42.2%) being third-year students, followed by smaller distributions across first-year (13.3%), second-year (17.8%) and fourth/final-year students (13.3%), while 13.3% marked themselves as not relevant to the category. The final graph asks about previous experience with virtual reality (VR) systems, revealing that a significant majority (71.1%) have never used VR before. Among those who have, PlayStation VR is the most used (13.3%), while Oculus Meta Quest 3, HTC Vive XR Elite and Pico 4 each have an equal but lower usage rate of 4.4%. A minimal number (2.2%) have engaged with VR games in Samarahan. Overall, the data suggests that most respondents are non-medical students in their early 20s, with limited exposure to VR technology.

The age distribution suggests that most respondents are in their early to mid-20s, likely indicating that they are mostly university students, possibly in their undergraduate years but non-students are still included in this survey. The second graph, where a majority are not medical students, implies that the survey includes participants from various academic backgrounds, meaning the VR gamification project may need to accommodate users with little to no medical knowledge. The third graph reinforces this by showing that most respondents are in their third year, suggesting they have some academic experience but may still require engaging and simplified content to aid learning. The final graph shows a crucial insight, which is the overwhelming lack of VR experience (71.1%) among respondents implies that many users will be unfamiliar with VR technology, requiring an intuitive and user-friendly design. Additionally, the relatively low engagement with existing VR systems suggests that exposure to VR in their academic or personal lives has been minimal, meaning the gamification elements must be accessible even to complete beginners.

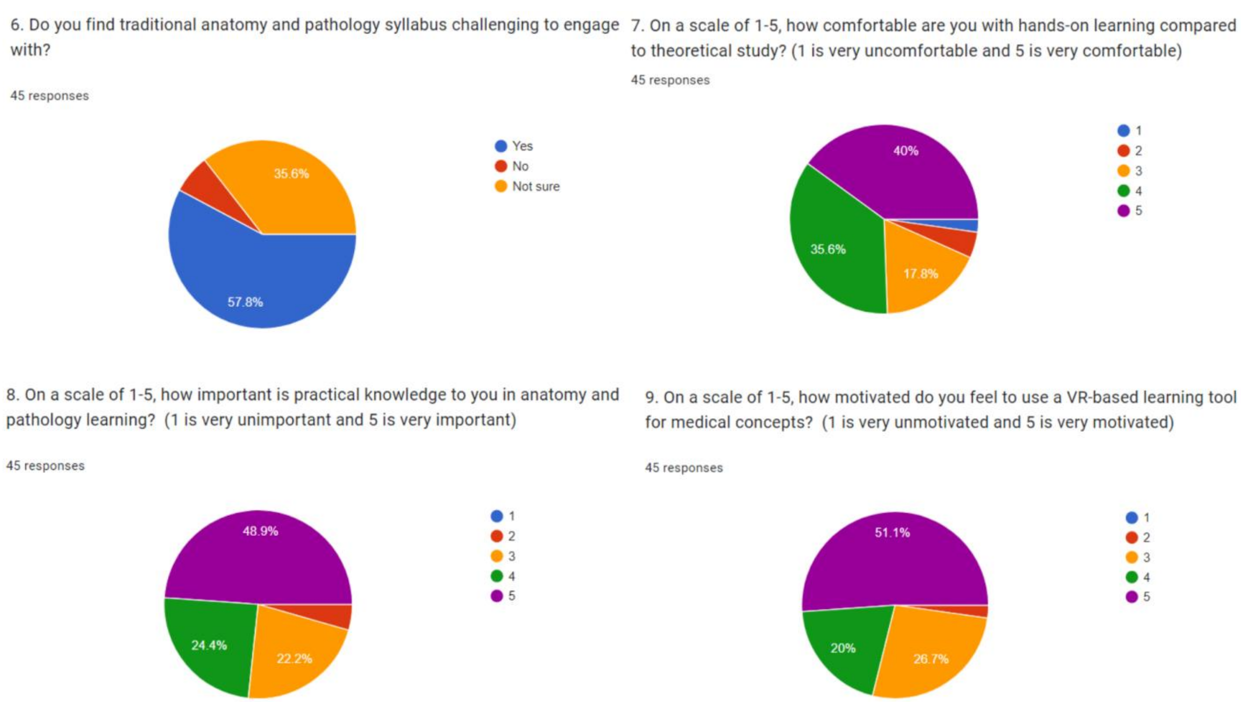

Figure 3.3 User's basic background

The first graph shows that a majority (57.8%) of respondents find the traditional anatomy and pathology syllabus challenging to engage with, while 36.6% are unsure and only a small fraction do not find it difficult. The second graph, which measures comfort with hands-on learning compared to theoretical study, reveals that most respondents are comfortable, with 40% rating their comfort level at 5 (very comfortable) and 35.6% at 4, while lower ratings are minimal. The third graph highlights the importance of practical knowledge in anatomy and pathology learning, with nearly half (48.9%) rating it as very important (5), 24.4% rating it as 4 and only a small portion considering it unimportant. The final graph examines motivation for using a VR-based learning tool for medical concepts, where more than half (51.1%) rate their motivation as 5 (very motivated), followed by 26.7% at 4, indicating strong enthusiasm for VR-based learning.

The data implies that many students struggle with traditional learning methods in anatomy and pathology, suggesting a need for alternative, engaging approaches. The high comfort level with hands-on learning supports the idea that interactive and practical methods could enhance comprehension and engagement. The strong emphasis on the importance of practical knowledge indicates that students value experience-based learning, which aligns well with the potential benefits of VR gamification. Finally, the high motivation for VR-based learning suggests that students are open to and interested in integrating technology into their education, reinforcing the feasibility of a VR-based gamified approach to make learning more effective and engaging.

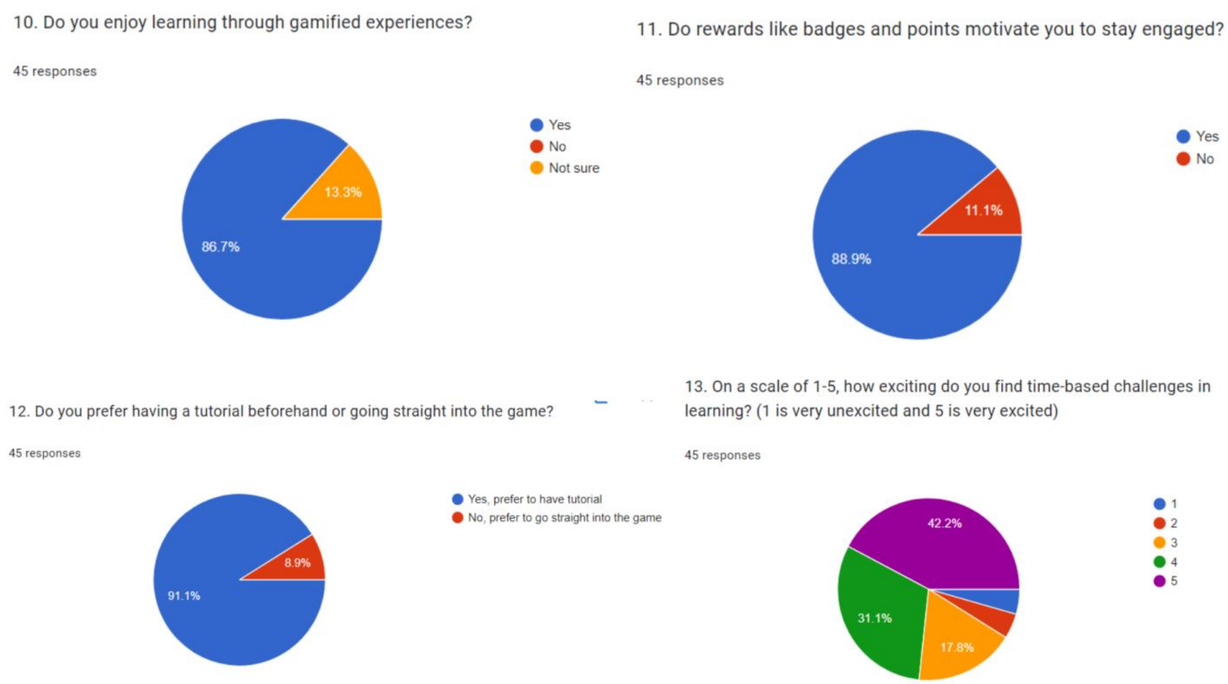

Figure 3.4 Gamification preferences

The first graph shows that an overwhelming majority (86.7%) of respondents enjoy learning through gamified experiences, while only 13.3% are unsure and none explicitly dislike it. The second graph indicates that most participants (88.9%) find rewards like badges and points motivating, with only 11.1% stating otherwise. The third graph highlights a strong preference (91.1%) for having a tutorial before starting a game, with only 8.9% preferring to jump straight in. The final graph assesses excitement levels regarding time-based challenges in learning, where 42.2% rate their excitement at the highest level (5), followed by 31.1% at 4, indicating that most participants find such challenges engaging. Only a small portion rates their excitement as low.

These findings imply that incorporating gamification into the VR learning experience will likely be well-received, as most students enjoy gamified learning and are motivated by reward-based mechanics. The strong preference for tutorials suggests that a structured step-by-step process will be crucial for ensuring students understand how to navigate and engage with the VR environment effectively. The high excitement levels for time-based challenges indicate that competitive or timed elements could enhance engagement, making the learning experience more immersive and stimulating. Overall, these insights reinforce the potential success of a gamified VR learning system tailored to these preferences.

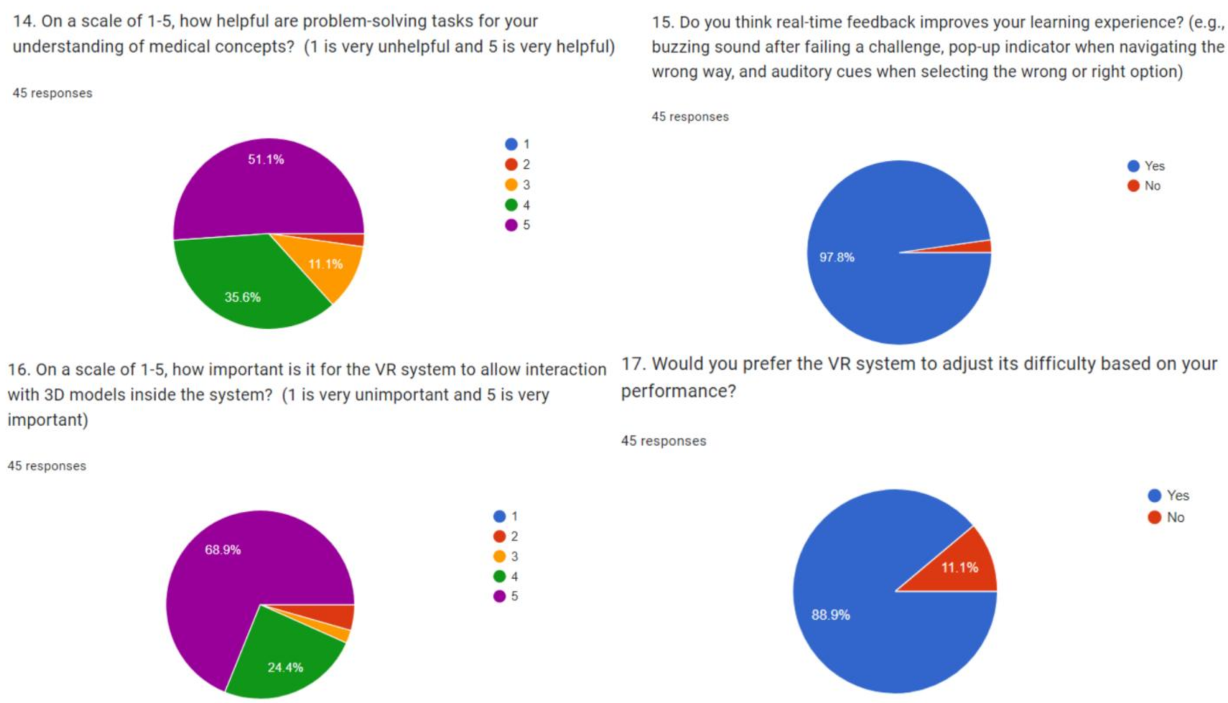

Figure 3.5: Continuation of gamification preferences

The first graph shows that problem-solving tasks are considered highly beneficial for understanding medical concepts, with 51.1% rating them as very helpful (5) and 35.6% at 4, indicating strong support for interactive learning methods. The second graph demonstrates that nearly all respondents (97.8%) believe real-time feedback enhances their learning experience, with only a negligible percentage disagreeing. The third graph highlights the importance of interacting with 3D models in a VR system, where 68.9% rated it as very important (5) and 24.4% at 4, reinforcing the value of hands-on engagement. The final graph shows that 88.9% of participants prefer the VR system to adjust difficulty based on their performance, while only 11.1% prefer a fixed challenge level.

These findings suggest that integrating problem-solving tasks into the VR experience would significantly enhance learning outcomes, as students find them useful for medical concept comprehension. The overwhelming preference for real-time feedback highlights the necessity of immediate response mechanisms, such as visual or auditory cues, to guide learners effectively. The strong demand for 3D model interaction indicates that a high level of interactivity should be a core feature of the VR system to maximize engagement and understanding. Lastly, the preference for adaptive difficulty suggests that a dynamic learning system, which adjusts based on the user's progress, would be more effective in maintaining motivation and providing an optimal challenge level for different learners.

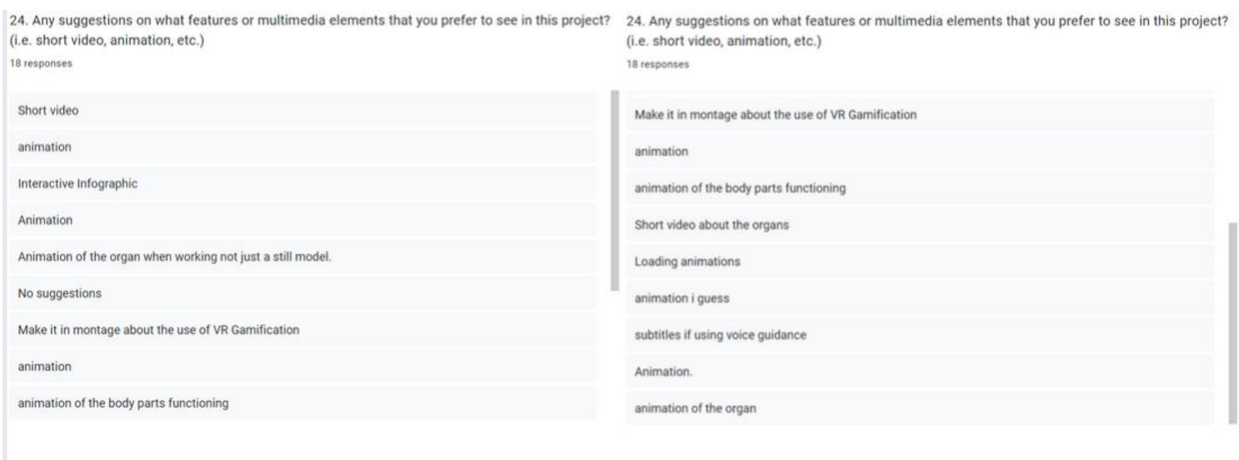

Figure 3.6: Respondent suggestions regarding PathoSphere gamification

The survey responses indicate that participants prefer various multimedia elements to enhance the VR project. Common suggestions include animations, especially for demonstrating organ functionality rather than just static models and short videos explaining medical concepts. Some respondents specifically mentioned interactive infographics and montages highlighting the use of VR gamification. Additional suggestions include loading animations for a smoother experience and subtitles for accessibility if voice guidance is used.

These preferences imply that users value dynamic, visually engaging content over static displays, reinforcing the need for high interactivity in the VR system. The emphasis on animations suggests that users find motion-based visuals more effective for learning complex medical concepts. The mention of voice guidance and subtitles highlights a need for accessibility and varied learning styles. Furthermore, the request for montages on VR gamification indicates that users may benefit from an introduction or tutorial explaining the system's purpose and mechanics before engaging with the content.

3.2.1.2 Functional Requirements

- 3D anatomical model interaction
- Navigation and challenges tutorial
- Real time text feedback for user guidance
- Point and click navigation
- Timer for challenges
- Play audio cue for challenges and navigation
- Animation for loading screen and organ display
- Difficulty adjustment

3.2.1.3 Non-Functional Requirements

- Smooth animation display
- Accurate 3D physics
- Secure player data

3.2.1.4 Software Requirements

Table 3.1: Software requirements

Software	**Description**

Unity3D	A cross-platform game engine for developing 2D/3D games, simulations and VR/AR experiences.
Visual Studio Code	An open-source code editor, used for writing C# code in this project.
Blender	A free and open-source 3D creation software widely used for modeling, animation, rendering, simulation and video editing.

3.2.1.5 Hardware Requirements

Table 3.2: Hardware requirements

Hardware	**Description**
Laptop Ryzen 5 GTX1050 16GB RAM	Sufficient requirement to use the development softwares.
PICO 4	A VR hardware to test PathoSphere.

3.2.2 Designing

In the design phase, wireframes and prototypes of the VR interface were created. This included layouts for menus, challenges and feedback systems. The design aimed to ensure user-friendly navigation and intuitive interaction with the 3D models. The process can be illustrated with diagrams shown below following the user's preference based from the survey conducted.

3.2.2.1 Activity Diagram

To demonstrate the flow of the system starting from entering PathoSphere to exiting the system, an activity diagram is used since it shows the flow from one occurrence to another (Kulkarni, R. N., & Srinivasa, C. K., 2022).

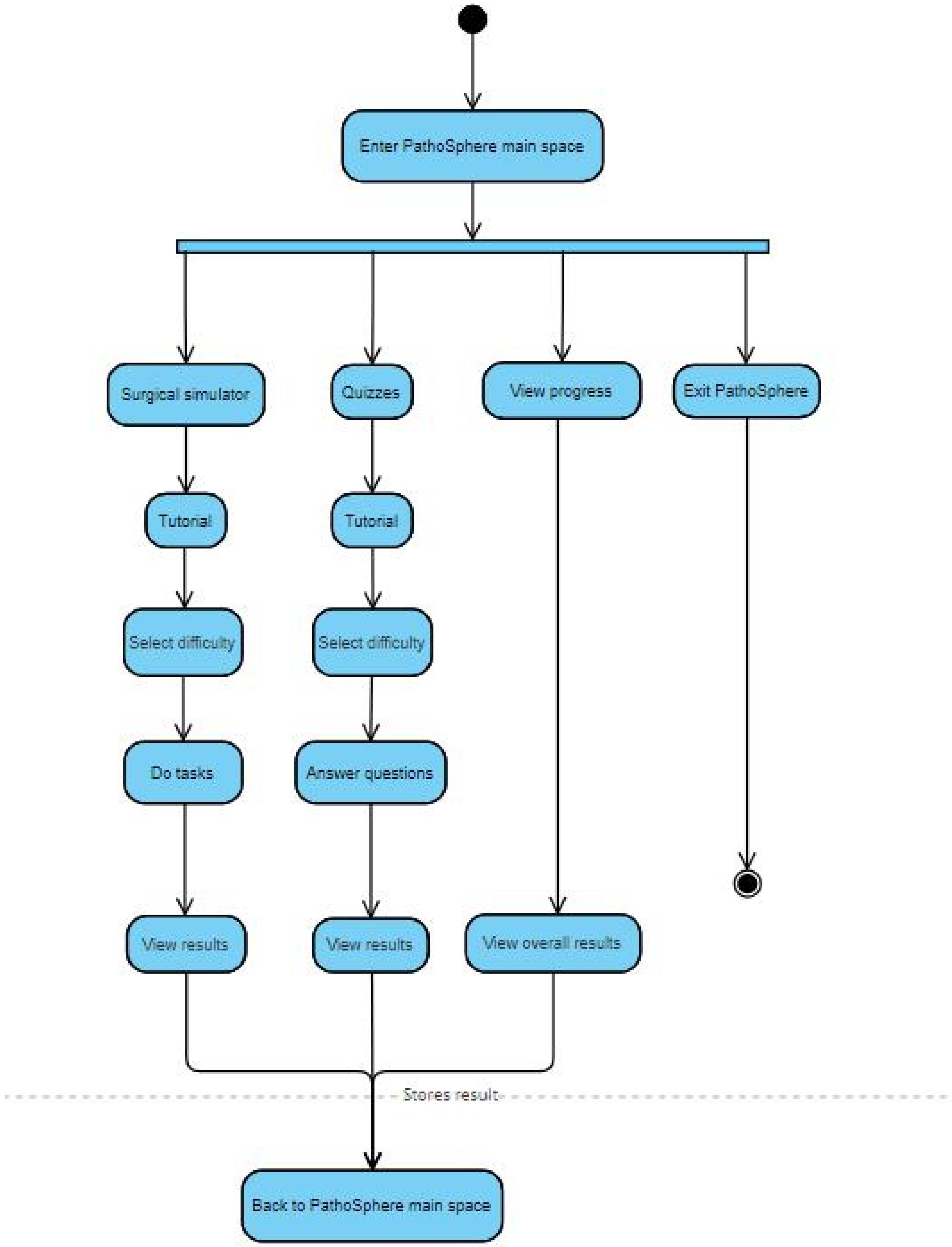

Figure 3.7: Activity diagram for PathoSphere gamification.

The activity flow of the PathoSphere VR gamification system begins when the user enters the main space, where they can choose one of four activities which are the Surgical Simulator, Quizzes, Viewing Progress, or Exiting the System. If the user selects the Surgical Simulator, they first complete a tutorial, choose a difficulty level, perform assigned tasks and finally view their results, which are then stored. Similarly, if they opt for Quizzes, they complete a tutorial, select a difficulty level, answer quiz questions and then view their results, which are also stored. Alternatively, users can choose View Progress to check their overall stored results. At any time, they can select Exit PathoSphere to leave the system. Once results are stored, users return to the main space, allowing them to continue engaging with different activities or exit as needed. The process ensures an interactive and structured learning experience, guiding users through various tasks while tracking their progress within the VR environment.

3.2.2.2 Use Case Diagram

The system allows users to explore models, complete challenges and access progress tracking. The use case diagram outlines these interactions.

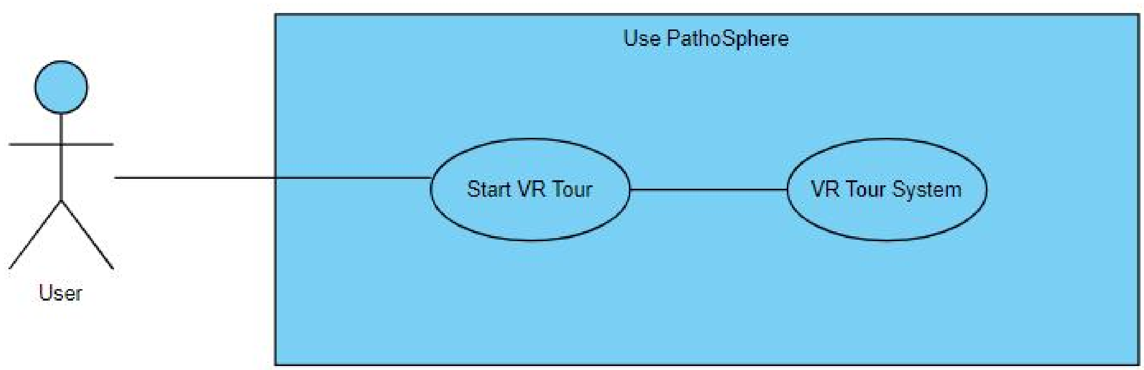

Figure 3.8: Use Case Diagram for Using PathoSphere

Figure 3.8 shows the use case diagram for using the PathoSphere system. Table below shows the description of the use case.

Table 3.3: Use Case: Start VR Tour

Use Case Name	Start VR Tour
Main Actor	User
Goal	To enter the PathoSphere VR environment.
Pre-condition(s)	PathoSphere is installed in VR device.
Post-condition(s)	User entered the PathoSphere VR environment.
Trigger	User select the system from the VR device.
Main Flow	1. User select the system from the VR device. 2. User enter the PathoSphere VR environment. 3. System loads up the navigation system, objects and environment. 4. User starts the VR Tour System

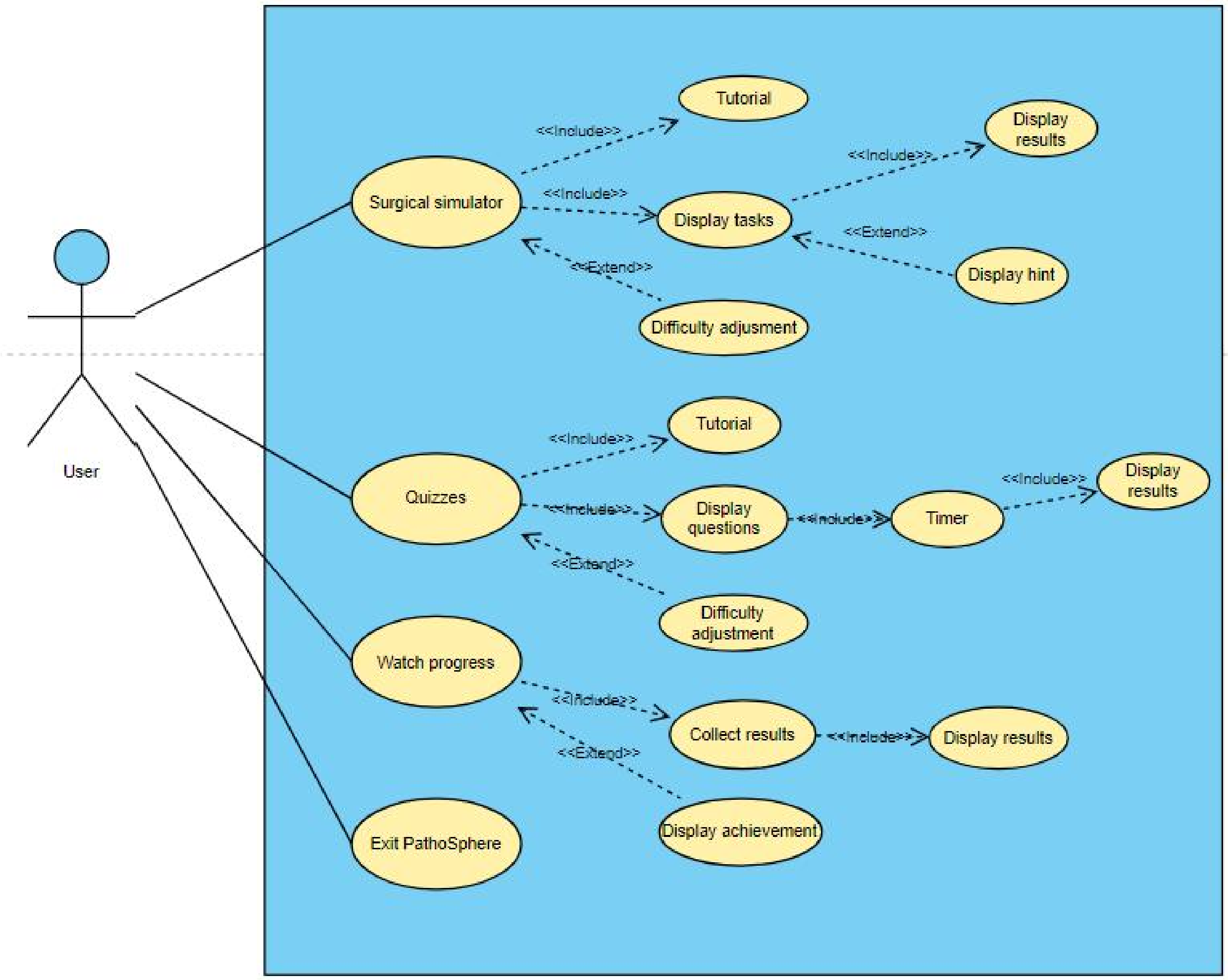

Figure 3.9: Use case diagram for PathoSphere gamification

The Use Case Diagram illustrates the interaction between a user and the PathoSphere VR Gamification System, showing four main activities: Surgical Simulator, Quizzes, Watching Progress and Exiting PathoSphere. The Surgical Simulator includes a tutorial for guidance, difficulty adjustment for varying challenge levels and displaying tasks, which can optionally extend to displaying hints for additional help. After completing tasks, users can view their results. The Quizzes section follows a similar structure, including a tutorial, difficulty adjustment and displaying questions, which integrates a timer to track progress. Users can then view results upon completion. The Watch Progress feature allows users to collect results, which automatically includes displaying results and extends to displaying achievements for motivational rewards. Lastly, the Exit PathoSphere use case represents the user leaving the system. The <<include>> relationships indicate that some features are mandatory within a use case, such as results display always being part of collecting results, while <<extend>> relationships highlight optional or conditional features like hints in the Surgical Simulator. This structure ensures a well-organized and interactive learning experience within the VR system.

Table 3.4: Use Case: Surgical Simulator

Use Case Name	Surgical simulator
Main Actor	User
Goal	To allow users to practice surgical tasks in a controlled and interactive VR environment.
Pre-condition(s)	User entered PathoSphere VR space.
Post-condition(s)	User entered the Surgical Simulator space.
Trigger	User navigate to the Surgical Simulator space.
Main Flow	1. User entered the PathoSphere main environment. 2. User navigate to Surgical Simulator area. 3. User entered Surgical Simulator space. 4. Module loads up the simulation.

Table 3.5: Use case: Quizzes

Use Case Name	Quizzes
Main Actor	User
Goal	To test the user's knowledge through interactive quizzes related to anatomy and pathology.
Pre-condition(s)	1. User entered PathoSphere VR space. 2. User navigate through Quizzes area near organ module.

Post-condition(s)	User can answer the quizzes with countdown.
Trigger	User selected the quiz.
Main Flow	1. User selects a quiz topic. 2. The system displays a series of questions. 3. User interacts with the quiz, with a timer if applicable. 4. Results are displayed at the end of the quiz.

Table 3.6 Use case: Watch Progress

Use Case Name	Watch Progress
Main Actor	User
Goal	Watch progress of quizzes attempted and Surgical Simulator played.
Pre-condition(s)	User enter PathoSphere environment.
Post-condition(s)	User able to see progress and achievement.
Trigger	User selects the option to view progress.
Main Flow	1. User enter PathoSphere main area. 2. User selects option to view progress. 3. System calculate user progress based on Quizzes attempted and Surgical Simulator played. 4. System displays progress.
Alternative Flow	1. User enter quizzes area or simulator area. 2. User selects option to view progress. 3. System calculate user progress based on Quizzes attempted and Surgical Simulator played. 4. System displays progress.

Table 3.7 Use case: Exit PathoSphere

Use Case Name	Exit PathoSphere
Main Actor	User
Goal	Exit the PathoSphere system.
Pre-condition(s)	User is in PathoSphere main space.
Post-condition(s)	User exits the PathoSphere system.
Trigger	User selects the option to exit.
Main Flow	1. User go in the main space of PathoSphere. 2. User selects the option to exit the system. 3. User exits the system.
Alternative Flow	1. User close the system from the VR device.

3.2.2.3 Sequence Diagram

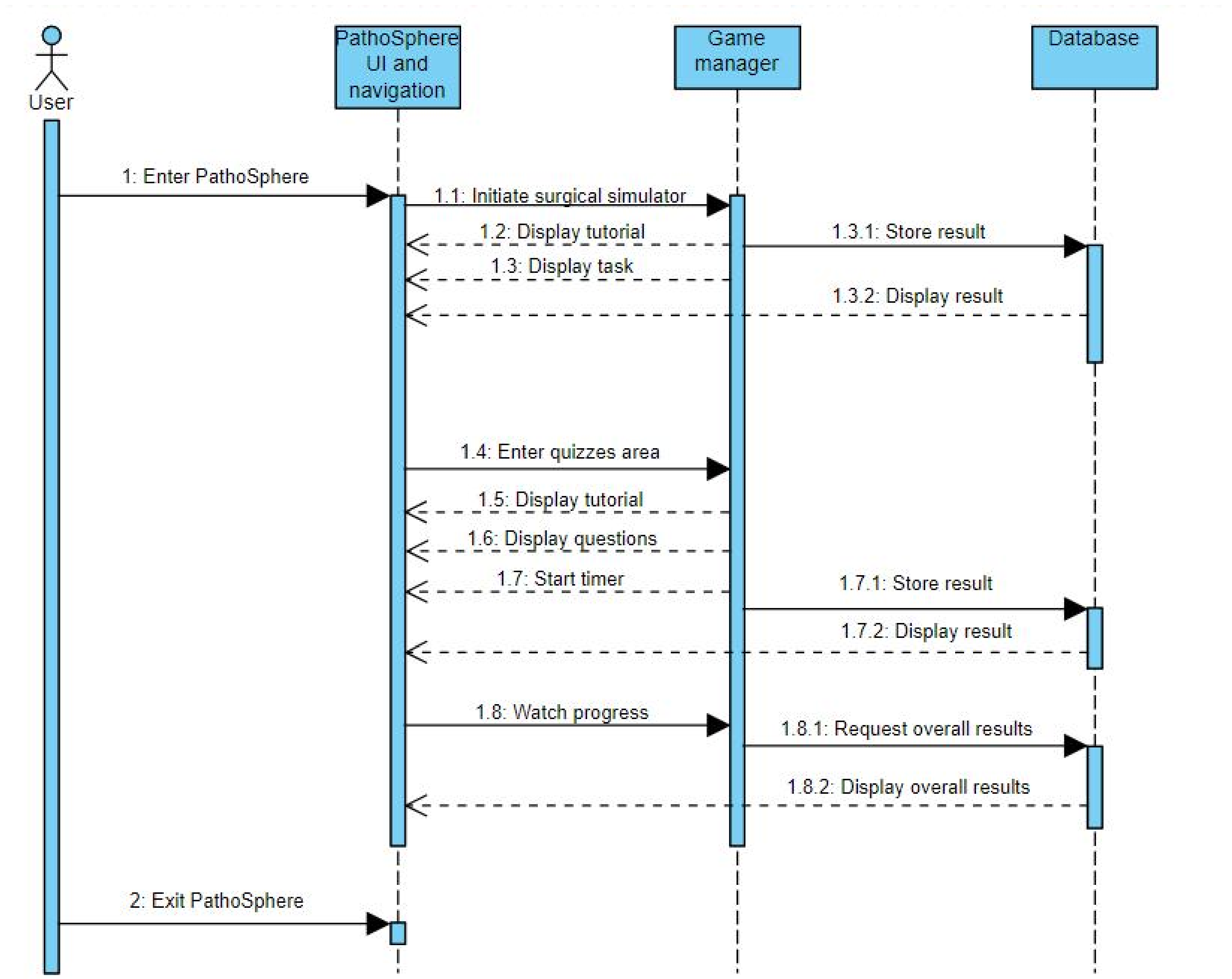

Figure 3.10: Sequence diagram for PathoSphere gamification

The sequence diagram illustrates the interaction between the user, the PathoSphere UI and navigation, the game manager and the built-in database during a session in the PathoSphere VR system. The user starts by entering PathoSphere, which triggers interactions with the UI. They first initiate the surgical simulator, prompting the system to display a tutorial and a task. Once the task is completed, the game manager stores the result in the database and the UI displays the stored result. Next, the user enters the quizzes area, where the system displays a tutorial followed by quiz questions. A timer starts to track the quiz and upon completion, the game manager stores the result in the database, which is then displayed to the user. The user can then choose to watch their progress, prompting the game manager to request overall results from the database, which are retrieved and displayed. Finally, the user exits PathoSphere, ending the session. This structured sequence ensures a smooth and interactive learning experience, allowing users to engage with simulations and quizzes while tracking and reviewing their progress efficiently.

3.2.2.4 Class Diagram

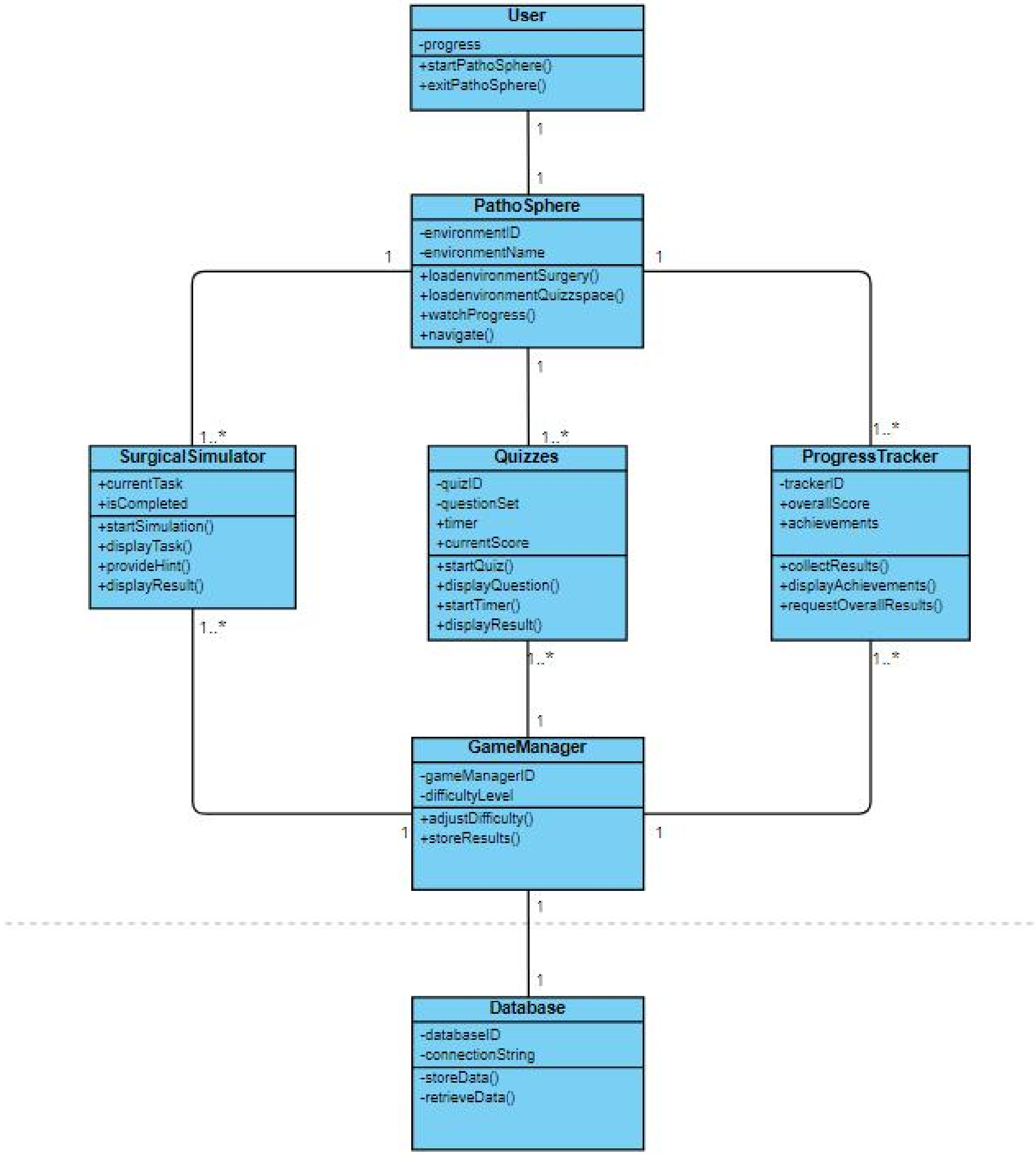

Figure 3.11: Class diagram for PathoSphere gamification development.

The class diagram represents the structure of the PathoSphere VR Gamification System, showing various classes, their attributes, methods and relationships. The user class contains attributes such as progress and methods to start and exit PathoSphere. The PathoSphere class manages the environments, allowing users to load either a surgical simulation or quiz space, navigate and watch progress. It has a one-to-many relationship with the SurgicalSimulator, Quizzes and ProgressTracker classes, meaning multiple instances of these components can exist within a single PathoSphere environment.

The SurgicalSimulator class handles the simulation tasks, tracking the current task and completion status and provides methods to start the simulation, display tasks, provide hints and display results. The Quizzes class manages quiz-related attributes like quiz ID, question set, timer and current score. It has methods to start a quiz, display questions, start the timer and display results. The ProgressTracker class tracks user performance, including overall scores and achievements and provides methods to collect results, display achievements and request overall results.

The GameManager class is responsible for adjusting the difficulty level and storing results, interacting with both SurgicalSimulator and Quizzes in a one-to-many relationship. Finally, the Database class is responsible for storing and retrieving data, ensuring that results and progress are saved. The GameManager has a one-to-one relationship with the Database, indicating it directly manages result storage.

Overall, this class diagram outlines how different components interact in the PathoSphere VR system, ensuring a structured approach to user experience, game management and data handling.

3.2.2.5 Interface Design

Wireframes illustrate the VR layout, focusing on intuitive menus and interactive elements. The design prioritizes usability and engagement. It also shows the interface for the surgical simulator and quizzes.

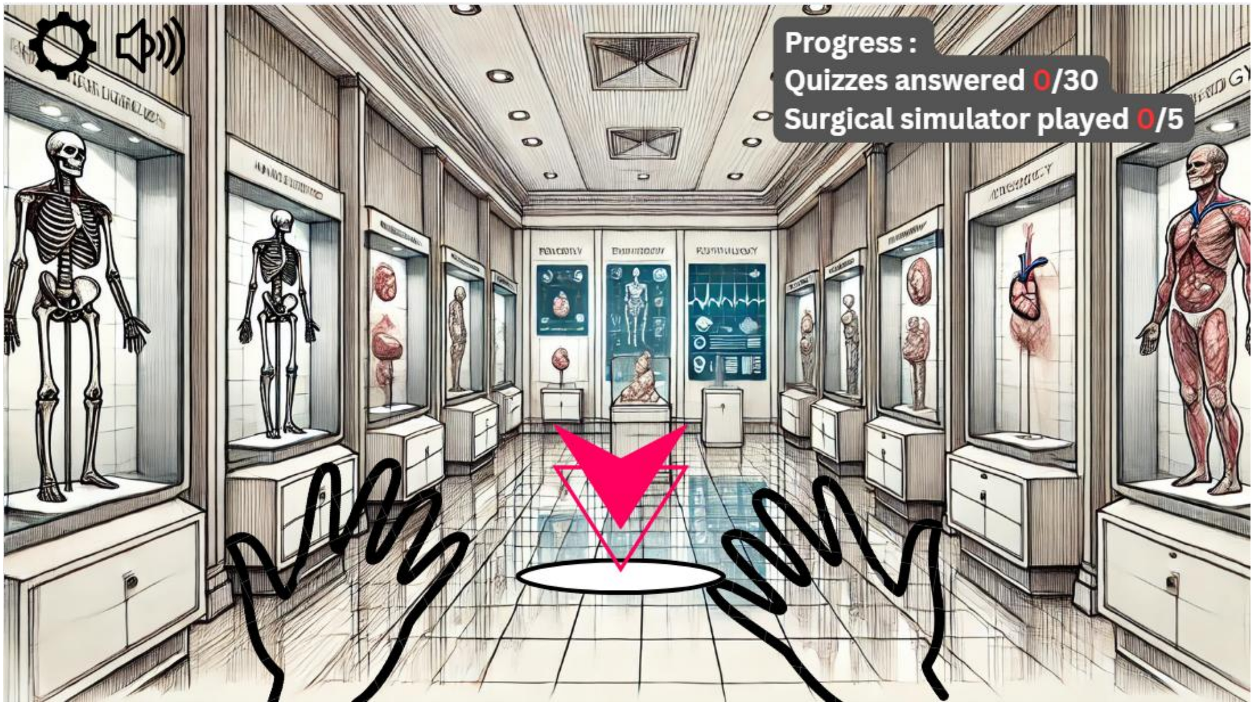

Figure 3.12: Interface for the main lobby of PathoSphere

Figure 3.12 shows the main lobby interface for PathoSphere. The navigation system will be similar to online map navigation that utilities the click and point movement but free movement is also included. The progress are already shown as soon as user enter the system. There are several hints such as texts or arrow to inform the user what and how to use certain function. The final design will be smoother and more appealing and the background will be change to be as similar as the real pathology and anatomy museum.

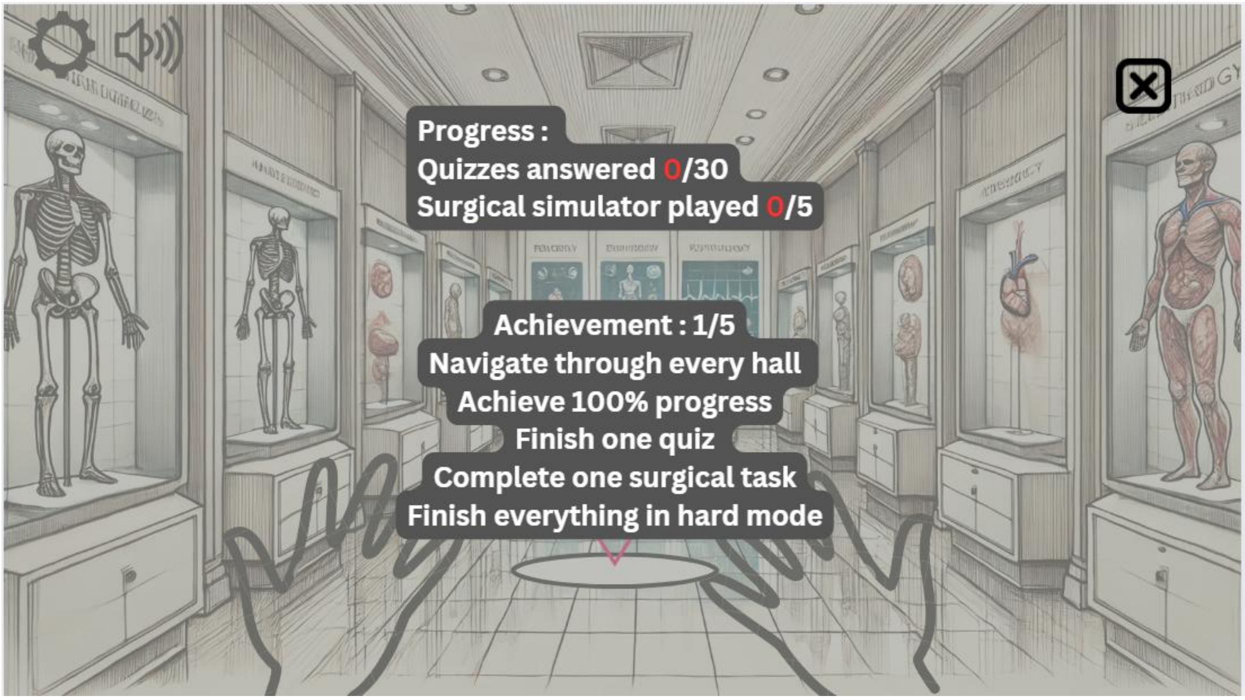

Figure 3.13: Progress including details

After selecting the progress, an achievement list is shown to add more "game-like" elements to this system. User can use this achievement list as a guideline for the whole experience.

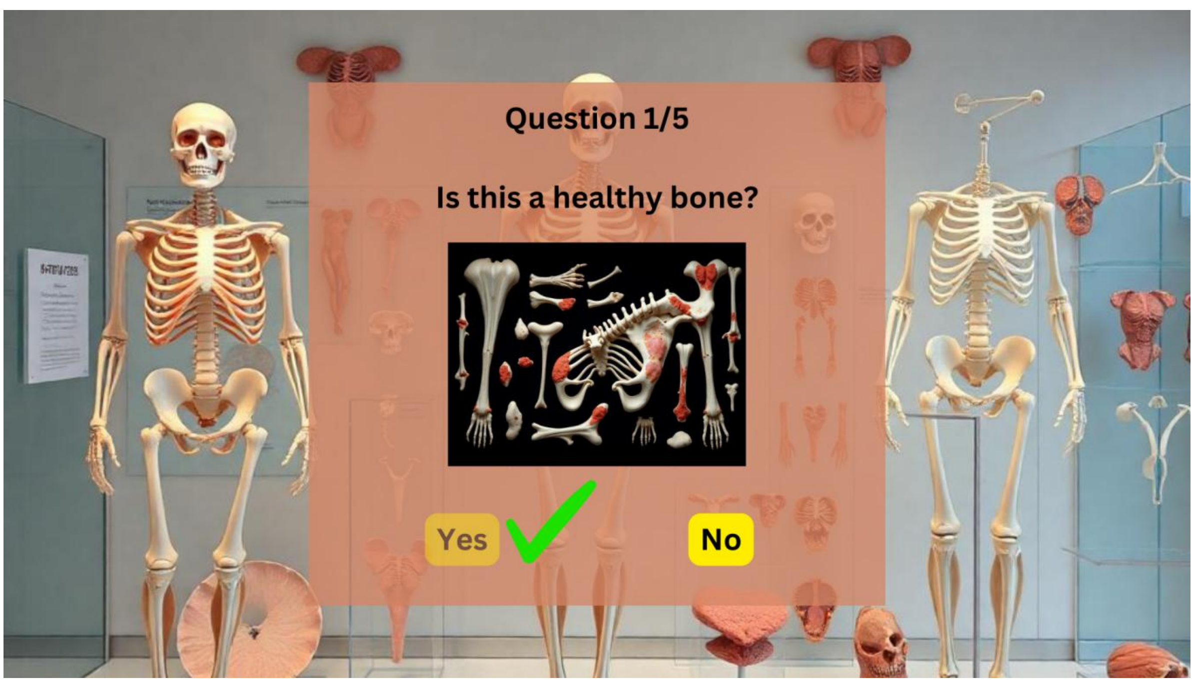

Figure 3.14: Quiz area for skeletons

This quiz area or section can be accessed while navigating each hallway starting from the main lobby of PathoSphere. Each hallway will have different quiz depending on what is displayed. For example, a skeleton hallway will have skeleton-related quiz. User can study the hallway first using the animation and details before answering this quiz.

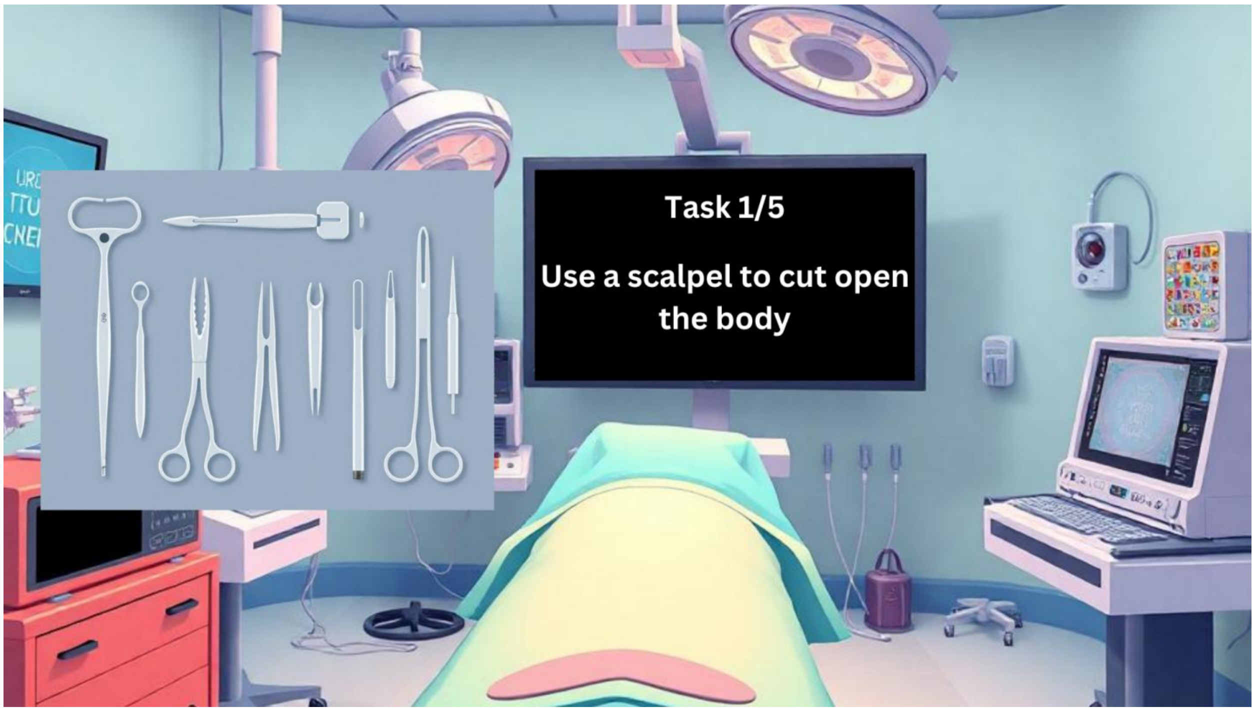

Figure 3.15: Surgical simulator area

This is an open area where user can leave unfinished tasks. This simulator will only uses a point and click with dragging mechanic where user can click an instrument, drag it towards the body and an animation of the result will be played. No complicated movement will be used as the goal of this is to introduced the flow of a surgery, organs involved and the instruments used.

3.2.3 Developing

The development phase focused on building the VR environment. It uses the previously mentioned hardware and software requirements as well as the funtional and non-funtional requirements for the system. Interactive features such as time-based challenges, problem-solving tasks and object-oriented interactions were integrated. The VR system was developed using Unity and optimized for Pico 4 hardware. Adaptive difficulty and progress-tracking features were implemented to personalize the learning experience.

3.2.4 Testing

Testing was conducted with a sample group of minimum 20 to 25 students. This phase evaluated the system's usability, engagement and educational impact. Bugs were identified and resolved and feedback from testers was used to improve functionality and content clarity. The testing process is shown below.

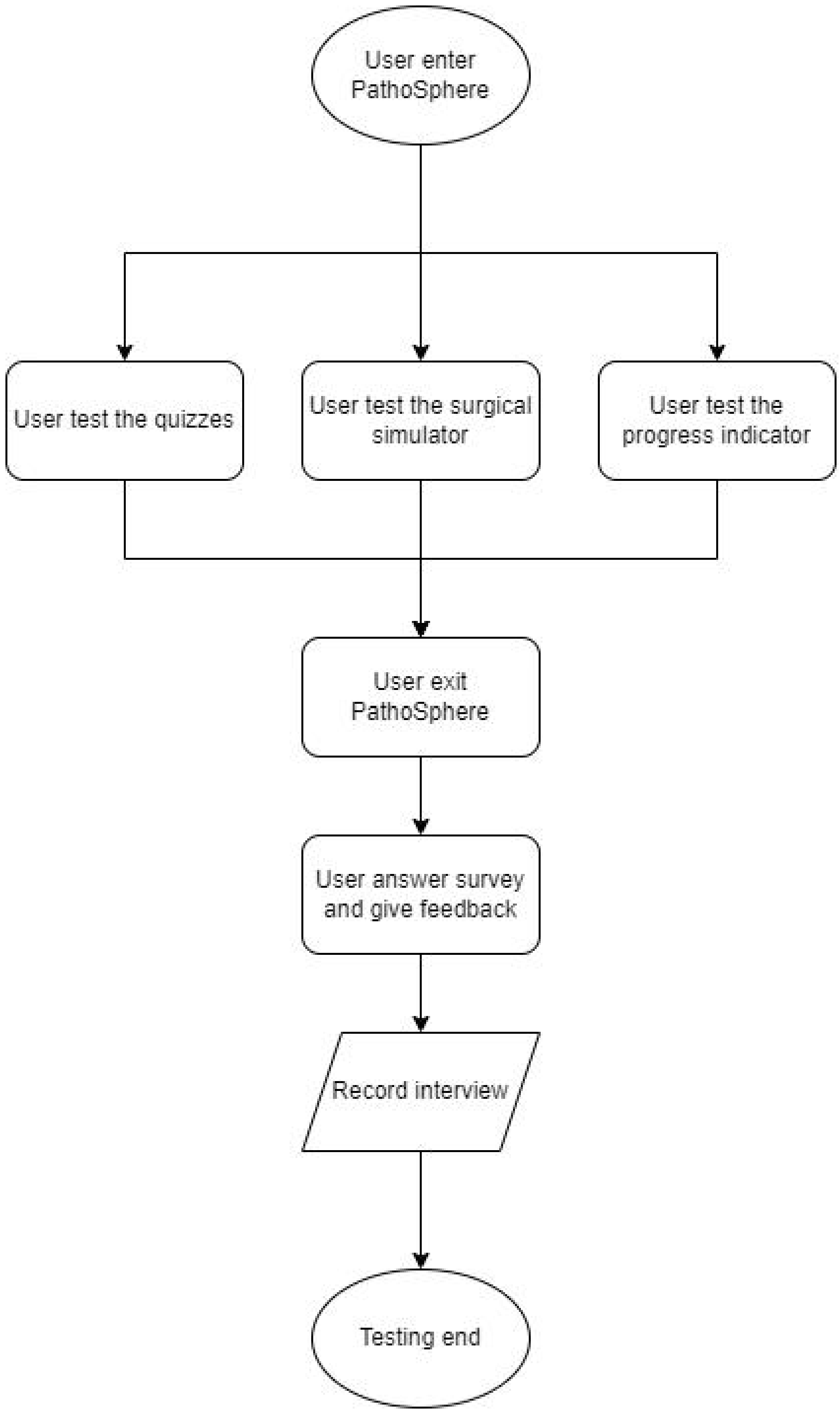

Figure 3.16: Flow diagram of the whole testing process

The flow diagram represents the user testing process for the PathoSphere system. It starts with the user entering PathoSphere, after which they can test different features, including the quizzes, the surgical simulator and the progress indicator. These three testing activities occur in parallel, allowing users to explore different functionalities independently.

Once the user completes testing, they exit PathoSphere. After exiting, they are required to answer a survey and provide feedback about their experience. Following the survey, an interview is recorded to gather more detailed insights. The process concludes with the end of the testing session.

This flow diagram provides a structured approach to user testing, ensuring that all aspects of the system are evaluated, feedback is collected and qualitative insights are recorded for further improvements.

3.2.5 Release

After the testing phase, the PathoSphere VR system was officially released to its intended users, which are students. The release phase focused on ensuring the system was accessible and functional across the target platforms, with clear documentation and tutorials to guide users. The main device that will be used is Pico 4. This release will mark one of the objectives as a success and achieved.

3.2.6 Feedback

Post-release, feedback was not collected. Instead, the feedback from testing phase will be used in improving before the release. Any other improvement after the release will not be done.

3.3 Summary

In conclusion, Chapter 3 detailed the requirement analysis and design process for the PathoSphere VR gamification system, following the Agile methodology. It outlined the planning, designing, developing, testing, releasing and feedback phases of the project. The planning phase involved setting objectives, user research and defining functional and non-functional requirements to meet user needs. The design phase focused on creating intuitive interfaces, interactive elements and gamified features, ensuring alignment with educational goals. The development phase utilized tools like Unity and Blender to develop and implement core functionalities, including quizzes, surgical simulators and progress tracking. Testing validated the system's usability and engagement before release, ensuring it met project goals. While no formal post-release feedback was collected, feedback from earlier stages was integrated to refine the final product. This methodology ensured a structured and user-focused approach, contributing in the successful deployment of an immersive and interactive VR learning experience for PathoSphere.

Chapter 4 : Implementation

4.1 Introduction

This chapter details the implementation of the PathoSphere project, focusing on the development environment, tools and techniques used to create the 3D virtual reality (VR) gamified experience for the UNIMAS Anatomy and Pathology Museum. The chapter covers the core technologies Unity3D, PICO SDK, Microsoft Visual Studio and Blender followed by in-depth discussion of the game implementation, including scene design, game objects, menus and the applied development techniques. The process of building the product and the methods used to ensure an effective educational VR experience are also described.

4.2 Unity3D Game Engine

Unity3D was selected as the primary game engine for PathoSphere due to its robust support for VR development, cross-platform capabilities and extensive asset management features.

4.2.1 Unity3D GameObjects and Components

In Unity3D, all elements within the VR environment are structured as GameObjects. Each GameObject can have multiple Components attached, such as Mesh Renderer for 3D visualization, Collider for physics interactions and custom scripts for interactivity. For PathoSphere, anatomical models, interactive UI elements and environmental props were each designed as GameObjects, enabling modular development and easy scalability.

4.2.2 Architecture and Compilation

The project follows a modular architecture, separating core gameplay logic, UI management and VR-specific interactions. Scripts are written in C# and compiled within the Unity environment. This approach supports iterative development and rapid prototyping, aligning with the Agile methodology adopted for the project1.

4.2.3 PICO SDK Integration

To ensure compatibility with the PICO 4 VR headset, the PICO SDK was integrated into Unity. This SDK provides APIs for head tracking, controller input and VR rendering optimizations, allowing seamless deployment and testing on the target hardware. The SDK also enables access to device-specific features such as hand tracking and spatial audio, enhancing immersion.

4.2.4 Microsoft Visual Studio

Microsoft Visual Studio serves as the integrated development environment (IDE) for writing and debugging C# scripts. Its advanced debugging tools and Unity integration streamline the coding workflow, enabling efficient troubleshooting and code management.

4.2.5 Blender

Blender was used for modifying and optimizing 3D anatomical models and environmental assets. Models were exported in formats compatible with Unity, ensuring accurate rendering and performance optimization within the VR environment. Blender's sculpting and texturing tools allowed for detailed, realistic representations of organs and museum exhibits.

4.3 The Game Implementation

4.3.1 Unity3D Gaming Scenes

The VR experience is structured into multiple scenes, each representing different sections of the Anatomy and Pathology Museum. Scenes include quiz zone and surgical simulator. Surgical simulator is being referenced as morgue room throughout the development and building process to help with the immersion of the whole system. Scene transitions are managed through Unity's Scene Management system, ensuring smooth navigation.

An intuitive menu system was implemented to facilitate navigation. The main menu provides access to learning modules, progress tracking and settings. In-game menus offer contextual options, such as pausing, reviewing objectives, or accessing help, all designed for VR interaction.

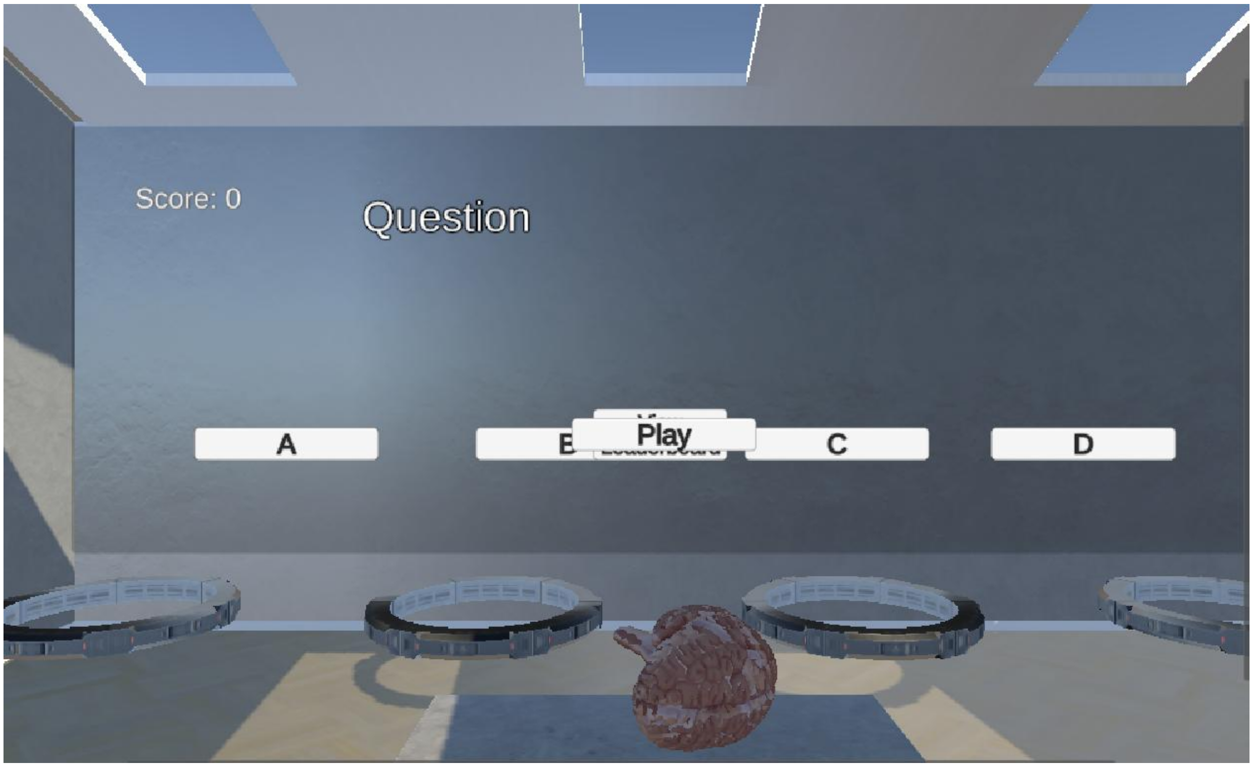

Figure 4.1: Screenshot of the 3D Quiz room

Figure 4.2: Screenshot of the Morgue Room

4.3.2 Game Objects

Key game objects include:

Anatomical Models: Interactive 3D representations of organs and body systems.

Figure 4.3: Screenshot of the 3D interactive model

Quiz Panels: UI elements for presenting questions and receiving user input.

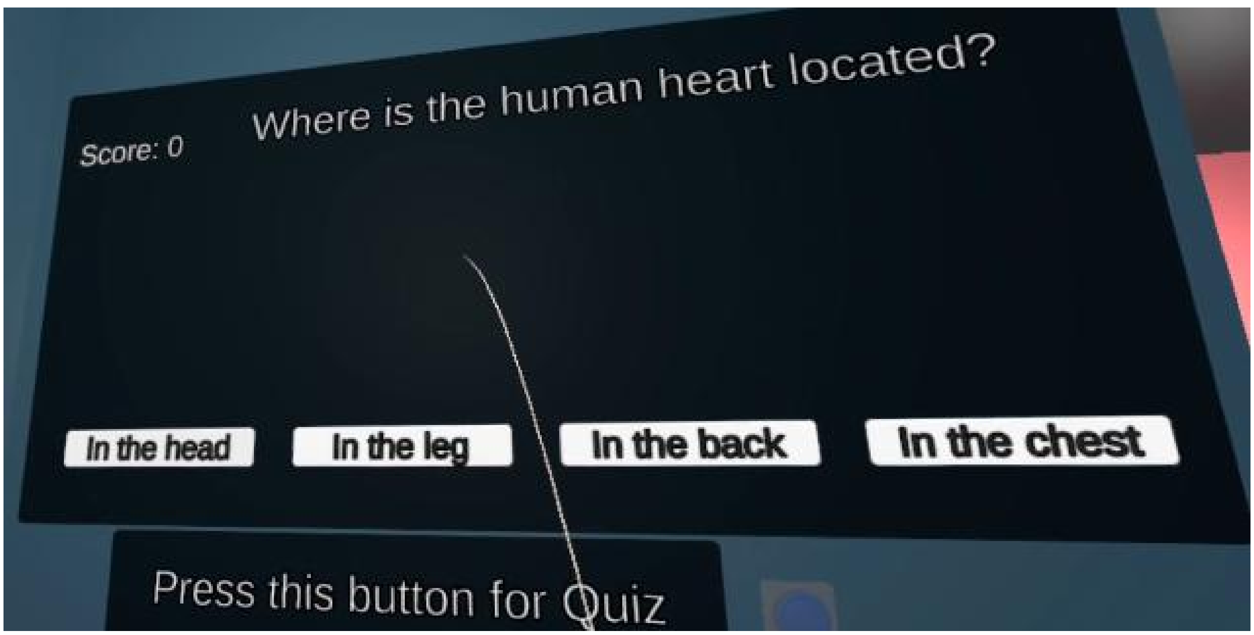

Figure 4.4: Quiz panel from unity development perspective

Feedback Systems: Visual and auditory cues to guide and motivate users.

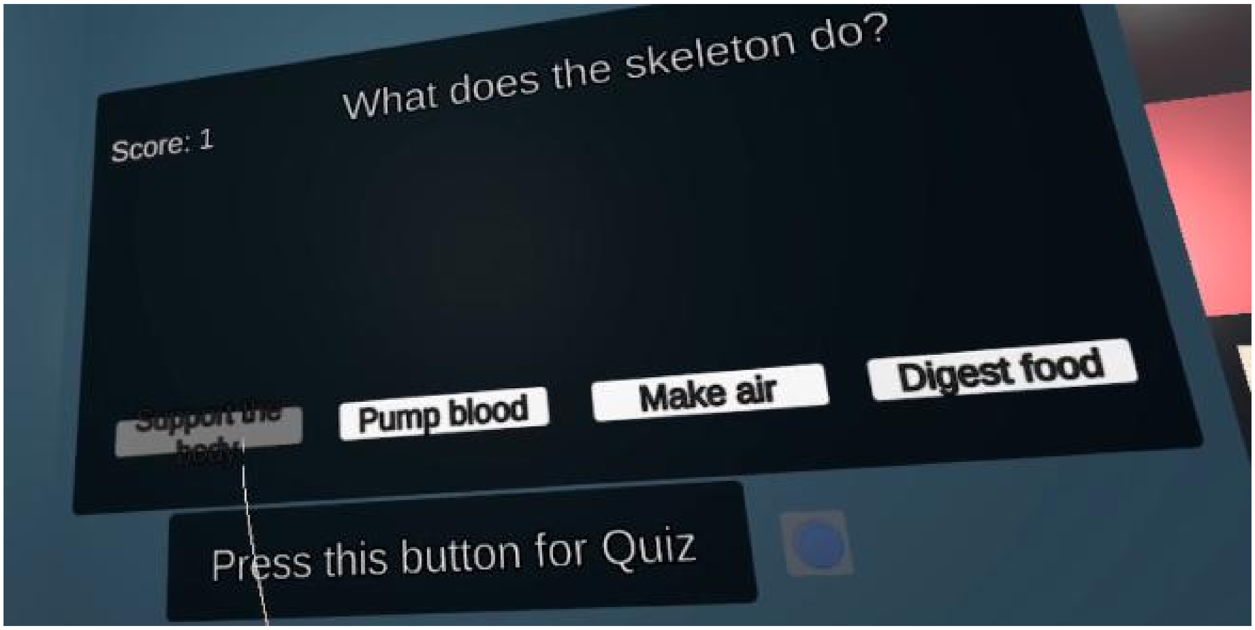

Figure 4.5: The panel button getting dimmer when controller is hovering

All objects are optimized for VR, with appropriate colliders and scripts to ensure responsive interaction.

4.3.3 Discussion

The modular design of game objects and scenes allows for iterative development and easy expansion. The use of Unity’s prefab system enables rapid prototyping and reuse of assets, supporting the Agile workflow. Integration with the PICO SDK ensures a smooth VR experience, while Blender assets provide high visual fidelity without compromising performance1.

4.4 The Game Techniques and Methods

The development process utilized several techniques to enhance engagement and learning:

Gamification: Incorporation of leaderboards system to motivate users.

```
leaderboard.Add((playerName, score));
leaderboard = leaderboard.OrderByDescending(x => x.score).Take(4).ToList();

showLeaderboardButton?.gameObject.SetActive(true);
```

Figure 4.6: Lines of codes to implement to leaderboard system

Interactive Challenges: Tasks such as organ identification, pathology quizzes and surgical simulations.

```
using UnityEngine;

Unity Script (1 asset reference) | 0 references
public class ScannerDetector : MonoBehaviour
{
    public Canvas canvasRoot; // Parent canvas holding all panels
    public GameObject defaultPanel; // Assign the "home" or default panel

    Unity Message | 0 references
    void OnTriggerEnter(Collider other)
    {
        OrganUITrigger organ = other.GetComponent<OrganUITrigger>();
        if (organ != null)
        {
            // Hide all panels first
            foreach (Transform child in canvasRoot.transform)
                child.gameObject.SetActive(false);

            // Show the panel linked to the organ
            if (organ.associatedPanel != null)
                organ.associatedPanel.SetActive(true);
        }
    }

    Unity Message | 0 references
    void OnTriggerExit(Collider other)
    {
        OrganUITrigger organ = other.GetComponent<OrganUITrigger>();
        if (organ != null)
        {
            // Hide all panels first
            foreach (Transform child in canvasRoot.transform)
                child.gameObject.SetActive(false);

            // Show only the default/home panel
            if (defaultPanel != null)
                defaultPanel.SetActive(true);
        }
    }
}
```

Figure 4.7: The code to scan the organ and set the panel active

These techniques are grounded in educational theory, aiming to maximize knowledge retention and user motivation1.

4.6 3D Virtual Reality Game for PICO

PathoSphere gamification is optimized for the PICO 4 VR headset, leveraging its hardware capabilities for immersive interaction. The system supports room-scale tracking, hand controllers and spatial audio, providing a comprehensive VR learning environment.

4.6.5 Discussion

The deployment on PICO 4 demonstrates the system's flexibility and adaptability. User feedback from initial testing informed iterative improvements, particularly in interaction design and comfort settings. The integration of hardware-specific features, such as hand tracking, further enhances the user experience.

4.7 Building the Product

The product was built through iterative cycles, following Agile methodology. Each sprint focused on implementing specific features, followed by user testing and refinement. The final build was packaged for PICO 4 deployment, with comprehensive documentation and support for future updates.

4.8 Summary

This chapter has outlined the technical foundation and implementation process for PathoSphere, highlighting the use of Unity3D, PICO SDK, Visual Studio and Blender. The modular architecture, gamification techniques and VR optimization collectively contribute to an engaging, effective educational tool for anatomy and pathology learning

Chapter 5: Testing

5.1 Introduction

This chapter presents the testing phase of the PathoSphere VR gamified learning system. Testing is crucial to ensure that the system meets both functional and non-functional requirements, guaranteeing usability, performance and reliability. The testing process included both functional and non-functional testing, following a structured test plan to validate the system's features and overall quality.

5.2 Functional Testing

Functional testing validates the software system against its functional requirements and specifications. The goal is to ensure that each function of PathoSphere operates as intended by providing appropriate input and verifying the output. The following test cases illustrate the functional testing performed on key features of the application.

Test Plan 1: Splash Screen

Test Objective:
To verify the navigation from the PathoSphere splash screen to the main menu.
Table 5.1: Test Case for Splash Screen

Test ID	Input Data	Expected Result	Actual Result	Pass/Fail
PB01	Open PathoSphere app	User should see splash screen before being navigated to main lobby	User able to see splash screen before being navigated to main lobby	Pass

Test Plan 2: Main Lobby

Test Objective:
To test the functionality of all main lobby gamification objects and ensure correct navigation.
Table 5.2: Test Case for Main Lobby

Test ID	Input Data	Expected Result	Actual Result	Pass/Fail
ML01	Grab the 3D Quiz button	User should be moved into 3D Quiz scene	User being moved into 3D Quiz scene	Pass

ML02	Grab the Morgue Room button	User should be moved into morgue room	User being moved into the morgue room	Pass
ML03	Grab the lobby quiz button	User should be shown a quiz panel	User being shown a quiz panel	Pass
ML04	Click the quiz panel buttons	User should be able to interact and answer the quiz properly	User able to interact and answer the quiz properly	Pass

Test Plan 3: Quiz Scene Interactions

Test Objective:

To ensure that interactive elements in the quiz game scene respond correctly to user actions.

Table 5.3: Test Case for Quiz Game Scene

Test ID	**Input Data**	**Expected Result**	**Actual Result**	**Pass/Fail**
QS01	Grab the brain	Brain 3D model should be grabbable	Brain 3D model is grabbable	Pass
QS02	Click the quiz panel buttons	User should be able to click quiz panel buttons	User able to click quiz panel buttons	Pass
QS03	Throw the brain model	Quiz answer should be selected and brain model return position	Quiz answer is selected and brain model return position	Pass
QS04	Answer the quiz	All the correct input and response should be shown	All the correct input and response is shown	Pass

Test Plan 4: Morgue Scene Interactions

Test Objective:

To ensure that interactive elements in the morgue game scene respond correctly to user actions.

Table 5.4: Test Case for Moruge Game Scene

Test ID	**Input Data**	**Expected Result**	**Actual Result**	**Pass/Fail**
MS01	Grab the	All 3D model should be able to	All 3D model is able to be	Pass

	organs and anatomy	be grabbed	grabbed	
MS02	Put the organs in the scanner	Information panel should be displayed	Information panel is displayed	Pass
MS03	Grab the cycle anatomy button	Anatomy should be cycled through muscles, organs and neuron structure	Anatomy is cycled through muscles, organs and neuron structure	Pass
MS04	Grab the return organs position button	All out of position organs should returned to their original position	All out of position organs are returned to their original position	Pass

Test Plan 5: VR Controller Input

Test Objective:

To verify that the VR controller input is accurately detected and processed by the system.

Table 5.5: Test Case for VR ontroller input

Test ID	Input Data	Expected Result	Actual Result	Pass/Fail
VR01	Use controller to select object	Object should be selected and interactable	Object selected and interactable	Pass

5.3 Non-Functional Testing

Non-functional testing assesses the system's quality attributes such as performance and compatibility.

Table 5.6: Test Case for VR ontroller input

Test ID	Test Case	Expected Result	Actual Result
Performance	Loading time and object rendering.	Loading time between scenes should not exceed 1 minute and object renders smoothly	Loading time between scenes does not exceed 1 minute but object does not render smoothly

Compatibility	Project build in PICO 4	Project build should work properly in PICO 4 device	Project build works properly in PICO 4 device

5.3.1 Usability Testing

During the usability testing phase of PathoSphere, a group of 11 representative users including medical and regular students were invited to interact with the VR system and provide structured feedback on its design, functionality and overall learning experience. The evaluation focused on aspects such as ease of navigation, clarity of instructions, engagement with gamified elements and the intuitiveness of interactive features. Overall, participants reported that the system was user-friendly and engaging with some users finding the interactive challenges and feedback loops effective in maintaining their interest and supporting their understanding of anatomical concepts while others experienced opposite results. Specific feedback observations and quantitative results from the usability surveys and testing sessions are documented in detail in the Appendix C, providing a comprehensive overview of user responses and areas identified for further improvement.

5.4 Summary

This chapter detailed the testing process for the PathoSphere VR system, including both functional and non-functional testing. All major features were validated through structured test cases, ensuring that the system operates according to specifications and delivers a reliable, user-friendly experience. The successful completion of these tests confirms the readiness of PathoSphere for deployment and further user adoption.

Chapter 6: Future Works and Conclusion

6.1 Introduction

This chapter summarizes the overall achievements of the PathoSphere project, discusses its current limitations and outlines potential future enhancements. The chapter concludes with a reflection on the significance of the work and its contribution to educational technology, particularly in anatomy and pathology learning through VR gamification.

6.2 Achievement

The PathoSphere project successfully developed an immersive, gamified VR learning environment tailored for the UNIMAS Anatomy and Pathology Museum. Key achievements include:

Analysis of Traditional VR Limitations:

- Conducted user surveys identifying key engagement gaps in static VR systems, including passive content consumption and limited interactivity.

- Established gamification as the solution to enhance exploration, knowledge retention and motivation.

Development of Game Mechanics:

- Implemented interactive challenges (e.g., organ identification quizzes, organ and anatomy interactions).

- Integrated real-time feedback loops and reward systems (e.g., achievement and progress tracking) to reinforce learning.

Pico 4 Hardware Validation:

- Optimized performance for Pico 4 through SDK integration, ensuring smooth rendering and controller responsiveness.

- Confirmed compatibility via stress tests, with all core features functioning seamlessly on the target hardware.

6.3 Limitations

While PathoSphere demonstrates significant progress, several limitations were identified:

- Hardware Dependency: The system is currently optimized for Pico 4 VR hardware, which may limit accessibility for users without compatible devices.

- Content Scope: The current version covers basic anatomy and pathology topics but lacks advanced modules or broader medical subjects.

- User Testing Scale: Testing was conducted with a limited group of students and educators; broader user studies are needed for comprehensive evaluation.

- Interactivity Constraints: Some interactive features are basic and could be further enhanced with more sophisticated haptic feedback. Some interactions with VR overlay cannot be implemented currently.

- Resource Intensity: High-quality 3D assets and VR rendering demand significant computing resources, potentially affecting performance on lower-end systems.

6.4 Future Enhancement

To address the above limitations and further improve PathoSphere, several enhancements are proposed:

- Multi-Platform Support: Expanding compatibility to other VR headsets and non-VR platforms (e.g., desktop or mobile) to increase accessibility.

- Content Expansion: Adding advanced modules, broader medical topics and integration with real-world case studies to deepen learning.

- Adaptive Learning: Incorporating AI-driven adaptive learning paths that personalize content and challenges based on user performance and preferences.

- Enhanced Interactivity: Implementing advanced haptic feedback, gesture recognition and voice commands for a more immersive experience.

- Collaborative Features: Introducing multiplayer or collaborative modes, enabling group learning and peer interaction within the VR environment.

- Broader User Testing: Conducting large-scale usability and effectiveness studies to validate learning outcomes and refine the system.

- Color Contrast Adjustment: Adjusting colors so that it is easy to look as a user.

- Leaderboard For Every Quiz: Adding leaderboard for every quiz instead of only in the quiz room.

- Adding difficulty adjustment on top of current non-adjusted single difficulty.

6.5 Conclusion

PathoSphere demonstrates the transformative potential of combining VR technology with gamification to enhance anatomy and pathology education. The project successfully addresses limitations of static learning resources by providing an interactive, engaging and user-centered VR experience. While certain challenges remain such as hardware dependency and the need for broader content the foundation laid by this project offers a scalable and adaptable model for future educational tools. Continued development and research will further solidify PathoSphere's role as an innovative solution in the field of educational technology, promoting deeper understanding and sustained motivation among learners.

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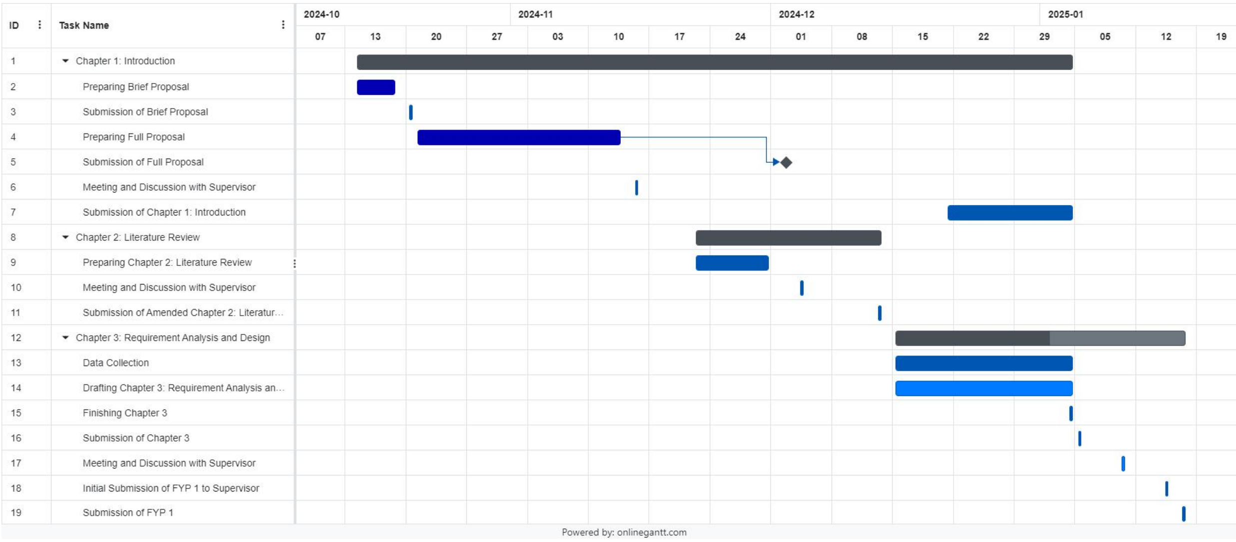
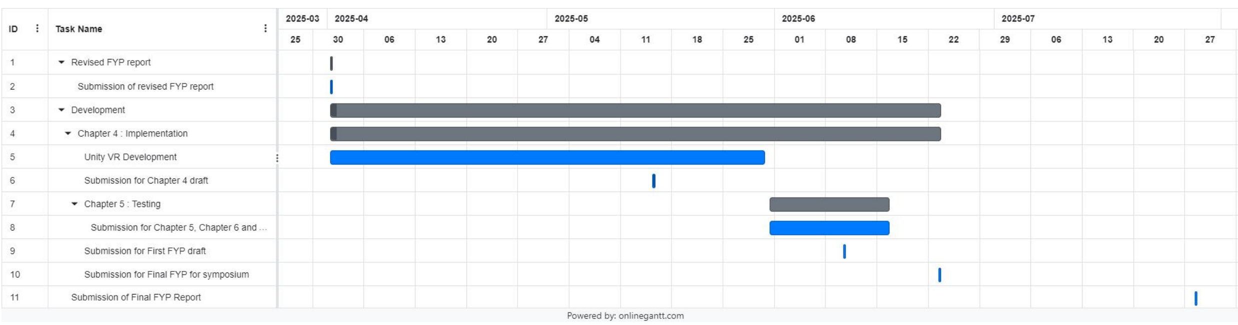
APPENDIX A

FYP 1 GANTT CHART





Fakulti Sains Komputer dan Teknologi Maklumat
Faculty of Computer Science and Information Technology

UNIMAS
UNIVERSITI MALAYSIA SARAWAK

UNIMAS/NC-19.03/04-32 Jld. 2 (42)

6 Disember 2024

Kepada Sesiapa Yang Berkenaan

Tuan/Puan

Kerja Lapangan Pelajar Tahun Akhir dari Universiti Malaysia Sarawak
- Janwillver Jainin

Dengan segala hormatnya perkara di atas adalah dirujuk.

Sukacita dimaklumkan bahawa pelajar berikut akan mengumpul maklumat untuk projek beliau.

Berikut adalah butir-butir pelajar:

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Tahun Pengajian	:	4
Tajuk Projek	:	*PathoSphere Enhanced Learning through VR Gamification*
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Sehubungan itu, sukacita kiranya pihak tuan/puan dapat memberikan kerjasama kepada pelajar berkenaan untuk menyalurkan maklumat yang diperlukan bagi memenuhi syarat kursus. Segala maklumat yang diperolehi akan hanya digunakan untuk tujuan akademik semata-mata dan akan dijamin kerahsiaannya.

Ini adalah sebagai makluman kepada pihak tuan dan sekiranya ada sebarang pertanyaan, sila hubungi penyelia pelajar tersebut.

Sekian, terima kasih.

Siti Lydiawati binti Sahmat
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APPENDIX B

Google Form

PathoSphere Enhanced Learning through VR Gamification User Survey

Hi! I am Janwillver Jainin, a final year student from Faculty of Computer Science and Information Technology (FCSIT), University Malaysia Sarawak (UNIMAS). I am conducting a survey for a project regarding gamifying a VR system which is called PathoSphere. The main purpose for this survey is to further understand the user background, thoughts, preferences and needs for this project.

I would like to invite you to participate in this research project. Your participation is greatly appreciated. There are three sections in this survey with 24 questions and the total time to answer this is estimated to be around 10 minutes or less.

Section 1: User's Background and Needs
Section 2: Preferences for Gamification Features
Section 3: Interaction and Accessibility

The response results will be put in writing and presented as a part of this project. Please note that the **CONFIDENTIALLY** of your response is **assured**. All your information will not be shared and only be used for academic purposes.

Your kind response and time are valuable and most appreciated.

For further explanation or any inquiry, please contact me through WhatsApp (wa.me/60109585884).

Thank you in advance.

I agree to participate in the research study. I understand the purpose and natures of this study and I am participating voluntarily. I understand that I can withdraw from the study at any time, without any penalty or consequences. *

- ◯ Yes
- ◯ No

UNIMAS/NC-19.03/04-32 Jld. 2 (42)

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Kepada Sesiapa Yang Berkenaan

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No. Matrik	:	78076
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Sekian, terima kasih.

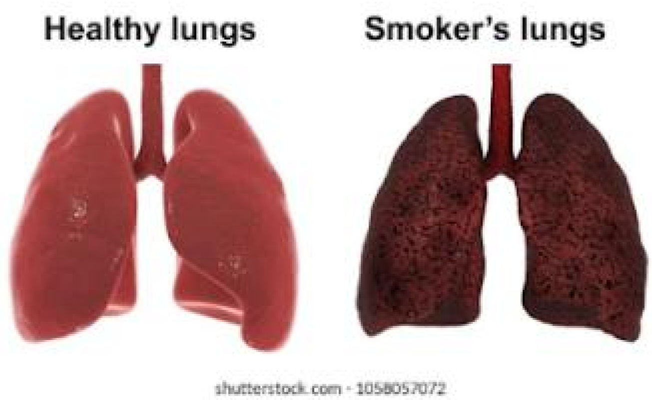
Siti Lydiawati binti Sahmat
Penolong Pendaftar Kanan

s.k. - **Timbalan Dekan, Prasiswazah,** FSKTM

Section 1: User's Background and Needs

Human anatomy : Focused more on human bodily structure such as separation of organs

Human pathology : Focused more on the diagnosis and research of the disease within human body



Examples of virtual reality (VR) and comparison between augmented reality (AR)

VR

VR

AR

1. How old are you? *

◯ 19-21

◯ 22-25

◯ 26 and above

2. Are you a medical student? *

- ◯ Yes
- ◯ No

3. What year of study are you currently in? *

- ◯ First year
- ◯ Second year
- ◯ Third year
- ◯ Fourth/Final year
- ◯ Not Relevant

4. Have you used one of these virtual reality systems before? (Select all that applies) *

- ☐ Oculus Meta Quest 3
- ☐ HTC Vive XR Elite
- ☐ PlayStation VR
- ☐ Pico 4
- ☐ No
- ☐ Other: ____________

5. Have you used educational VR tools for learning anatomy or pathology? *

- ◯ Yes
- ◯ No

5.1. Since you answered "Yes" in previous question, name the educational tools that you have used before.

Your answer

6. Do you find traditional anatomy and pathology syllabus challenging to engage with? *

- ◯ Yes
- ◯ No
- ◯ Not sure

7. On a scale of 1-5, how comfortable are you with hands-on learning compared to theoretical study? (1 is very uncomfortable and 5 is very comfortable) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

8. On a scale of 1-5, how important is practical knowledge to you in anatomy and pathology learning? (1 is very unimportant and 5 is very important) *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

9. On a scale of 1-5, how motivated do you feel to use a VR-based learning tool for medical concepts? (1 is very unmotivated and 5 is very motivated) *

- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5

Section 2: Preference for Gamification Features

Gamification meaning : Adding game mechanics and elements into non-game environment. Eg. Static VR, Websites, Learning tools etc.

10. Do you enjoy learning through gamified experiences? *

- ◯ Yes
- ◯ No
- ◯ Not sure

11. Do rewards like badges and points motivate you to stay engaged? *

- ◯ Yes
- ◯ No

12. Do you prefer having a tutorial beforehand or going straight into the game? *

- ◯ Yes, prefer to have tutorial
- ◯ No, prefer to go straight into the game

13. On a scale of 1-5, how exciting do you find time-based challenges in learning? (1 is very unexcited and 5 is very excited) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

14. On a scale of 1-5, how helpful are problem-solving tasks for your understanding of medical concepts? (1 is very unhelpful and 5 is very helpful) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

15. Do you think real-time feedback improves your learning experience? (e.g., buzzing sound after failing a challenge, pop-up indicator when navigating the wrong way, and auditory cues when selecting the wrong or right option) *

- ◯ Yes
- ◯ No

16. On a scale of 1-5, how important is it for the VR system to allow interaction with 3D models inside the system? (1 is very unimportant and 5 is very important) *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

17. Would you prefer the VR system to adjust its difficulty based on your performance? *

- ◯ Yes
- ◯ No

Section 3: Interaction and Accessibility

Section 3: Interaction and Accessibility

18. Do you think easy navigation is critical in a VR learning system? *

- ◯ Yes
- ◯ No

19. On a scale of 1-5, how useful would voice-based instructions be for guiding tasks? *

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

20. Would you like the system to allow you to revisit previous challenges? *

- Yes
- No

21. Do you feel accessibility options (e.g., reduced motion or visual aids) are important in a VR system? *

- Yes
- No

22. On a scale of 1-5, how long would you prefer a typical VR session to last, with 1 being very short and 5 being very long? *

- 1
- 2
- 3
- 4
- 5

23. Do you believe features that is engaging to the user make learning more effective? *

- Yes
- No

24. Any suggestions on what features or multimedia elements that you prefer to see in this project? (i.e. short video, animation, etc.)

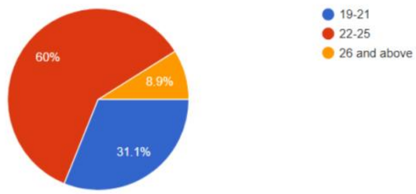
Your answer

APPENDIX C

Google Form Analytics

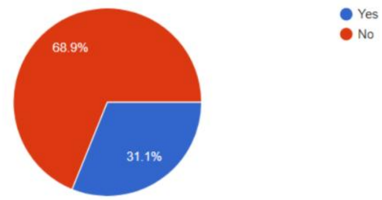
1. How old are you?

45 responses



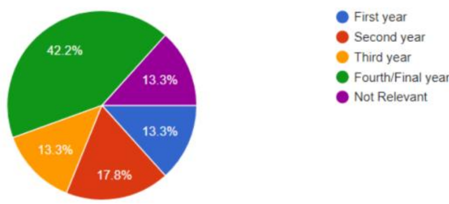
2. Are you a medical student?

45 responses



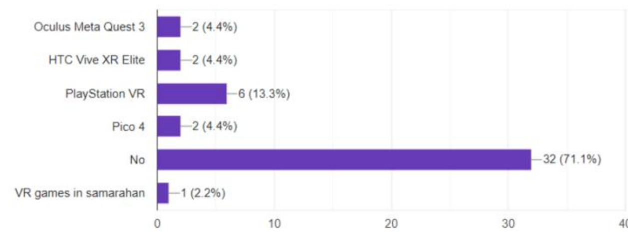
3. What year of study are you currently in?

45 responses



4. Have you used one of these virtual reality systems before? (Select all that applies)

45 responses



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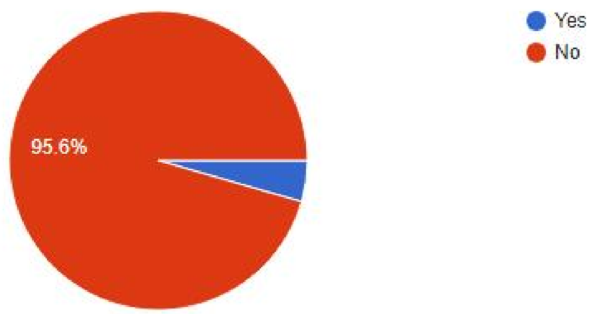
5. Have you used educational VR tools for learning anatomy or pathology?

45 responses



5.1. Since you answered "Yes" in previous question, name the educational tools that you have used before.

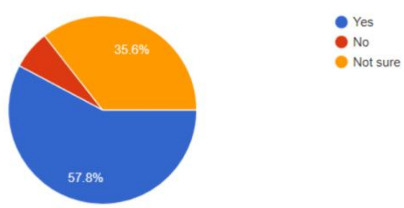
2 responses

Complete anatomy

Surgeon simulator

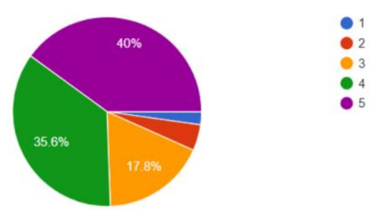
6. Do you find traditional anatomy and pathology syllabus challenging to engage with?

45 responses



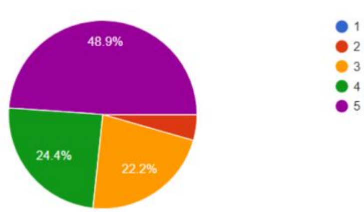
7. On a scale of 1-5, how comfortable are you with hands-on learning compared to theoretical study? (1 is very uncomfortable and 5 is very comfortable)

45 responses



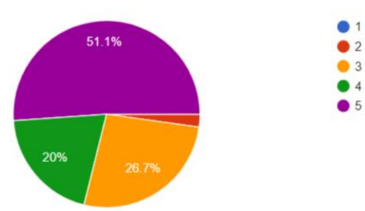
8. On a scale of 1-5, how important is practical knowledge to you in anatomy and pathology learning? (1 is very unimportant and 5 is very important)

45 responses



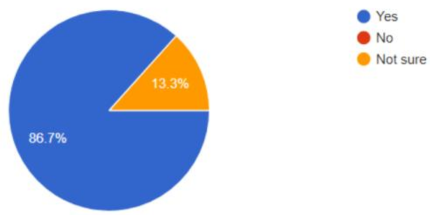
9. On a scale of 1-5, how motivated do you feel to use a VR-based learning tool for medical concepts? (1 is very unmotivated and 5 is very motivated)

45 responses



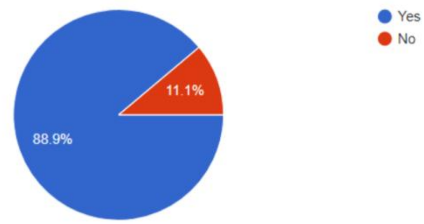
10. Do you enjoy learning through gamified experiences?

45 responses



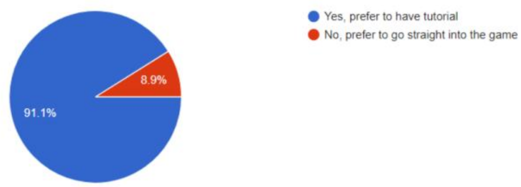
11. Do rewards like badges and points motivate you to stay engaged?

45 responses



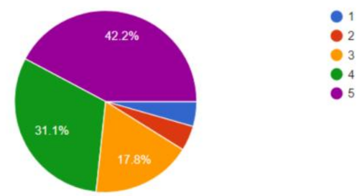
12. Do you prefer having a tutorial beforehand or going straight into the game?

45 responses



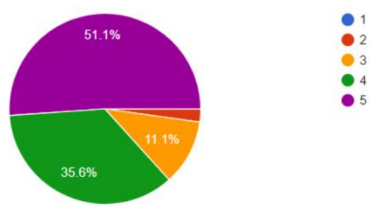
13. On a scale of 1-5, how exciting do you find time-based challenges in learning? (1 is very unexcited and 5 is very excited)

45 responses



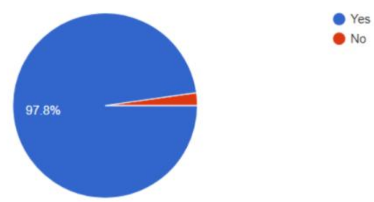
14. On a scale of 1-5, how helpful are problem-solving tasks for your understanding of medical concepts? (1 is very unhelpful and 5 is very helpful)

45 responses



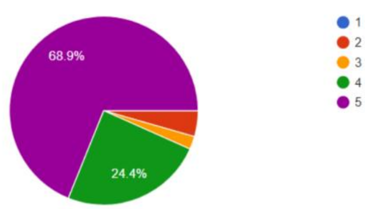
15. Do you think real-time feedback improves your learning experience? (e.g., buzzing sound after failing a challenge, pop-up indicator when navigating the wrong way, and auditory cues when selecting the wrong or right option)

45 responses



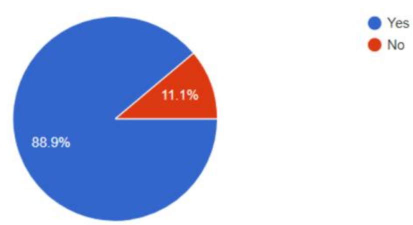
16. On a scale of 1-5, how important is it for the VR system to allow interaction with 3D models inside the system? (1 is very unimportant and 5 is very important)

45 responses



17. Would you prefer the VR system to adjust its difficulty based on your performance?

45 responses



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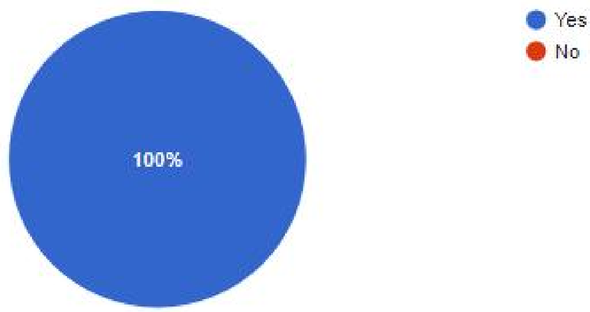
18. Do you think easy navigation is critical in a VR learning system?

45 responses



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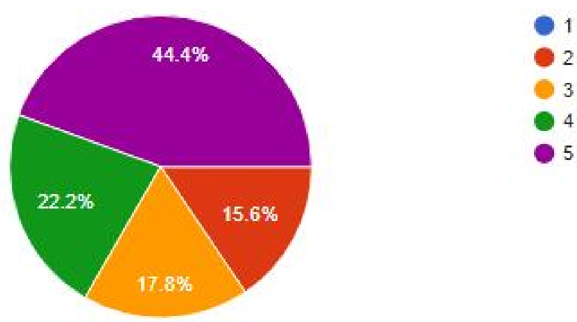
19. On a scale of 1-5, how useful would voice-based instructions be for guiding tasks?

45 responses



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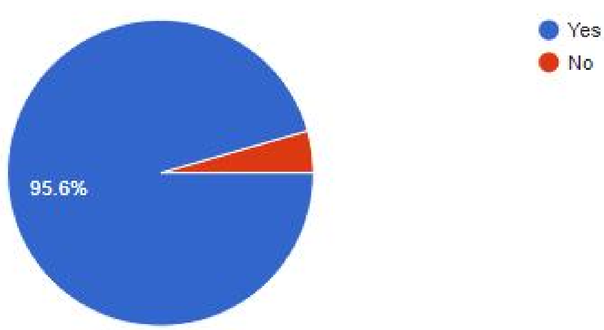
20. Would you like the system to allow you to revisit previous challenges?

45 responses



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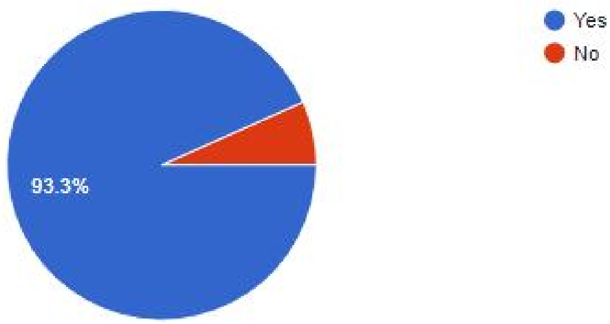
21. Do you feel accessibility options (e.g., reduced motion or visual aids) are important in a VR system?

45 responses



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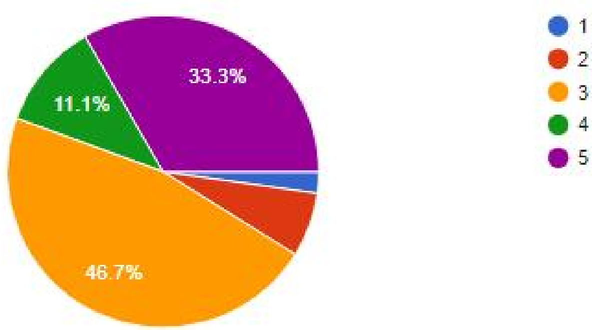
22. On a scale of 1-5, how long would you prefer a typical VR session to last, with 1 being very short and 5 being very long?

45 responses



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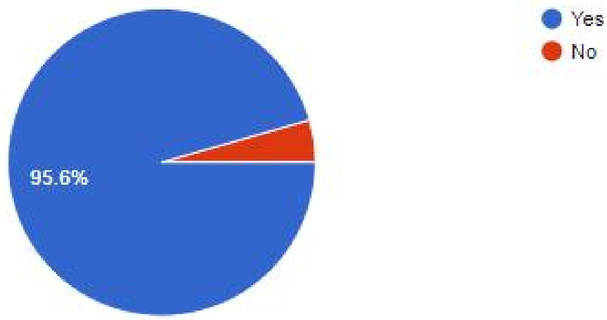
23. Do you believe features that is engaging to the user make learning more effective?

45 responses



24. Any suggestions on what features or multimedia elements that you prefer to see in this project? (i.e. short video, animation, etc.)

18 responses

- Short video
- animation
- Interactive Infographic
- Animation
- Animation of the organ when working not just a still model.
- No suggestions
- Make it in montage about the use of VR Gamification
- animation
- animation of the body parts functioning

24. Any suggestions on what features or multimedia elements that you prefer to see in this project? (i.e. short video, animation, etc.)

18 responses

- Make it in montage about the use of VR Gamification
- animation
- animation of the body parts functioning
- Short video about the organs
- Loading animations
- animation i guess
- subtitles if using voice guidance
- Animation.
- animation of the organ

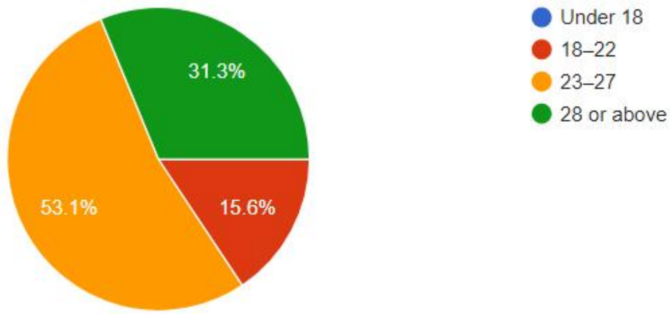
User Testing Survery

Section A : Pre-testing survey

What is your age group?

32 responses

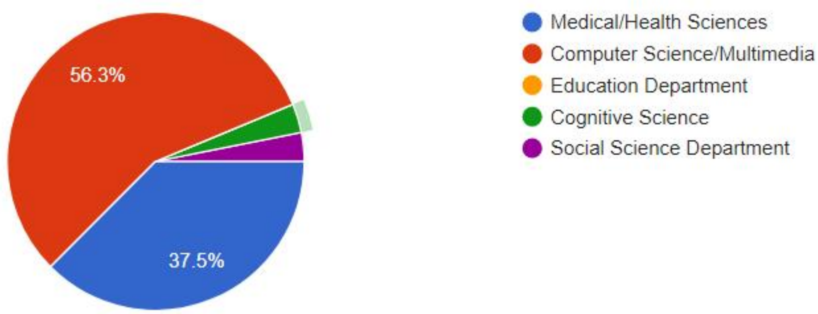
Copy chart



What is your academic background?

Copy chart

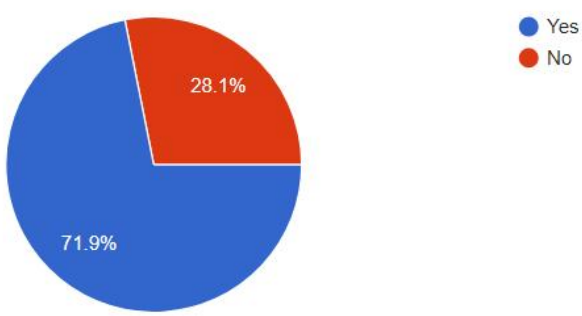
32 responses



Have you ever visited a physical anatomy or pathology museum before?

Copy chart

32 responses



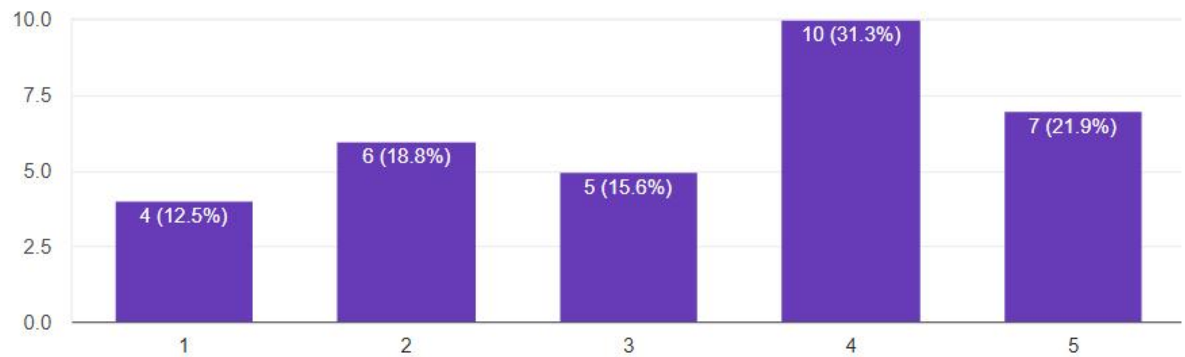
Section B: Pre-testing, Familiarity with VR, Anatomy and Pathology

Examples of virtual reality (VR)

Copy chart

How familiar are you with Virtual Reality (VR) technology?

32 responses



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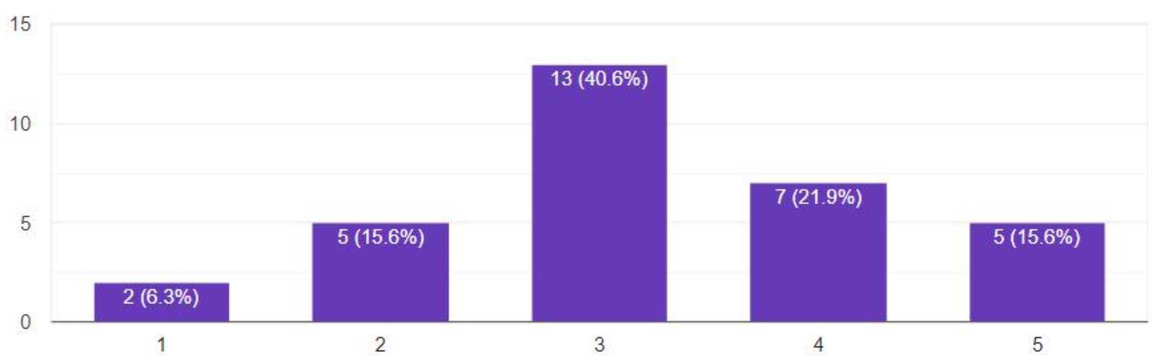
How would you rate your knowledge of human anatomy/pathology?

32 responses



Section C: Pre-testing, Expectations

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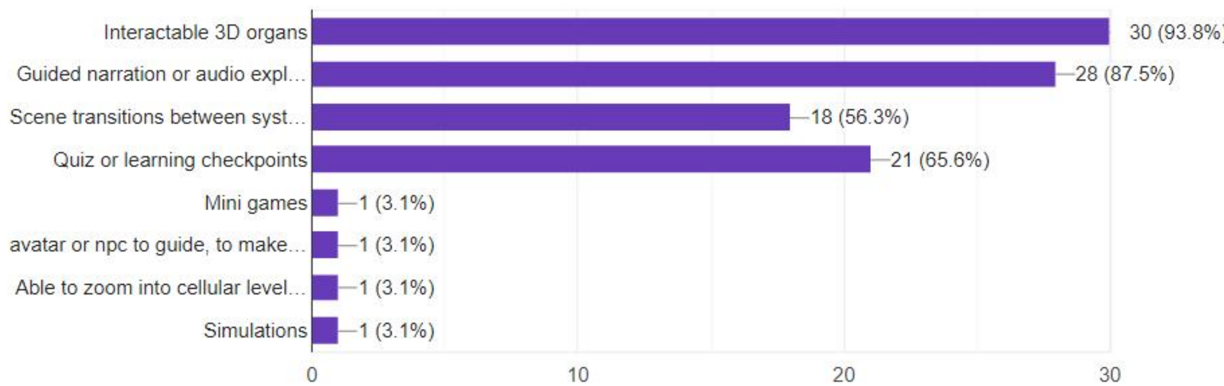
What features do you expect in a VR anatomy museum? (Select all that apply)

32 responses



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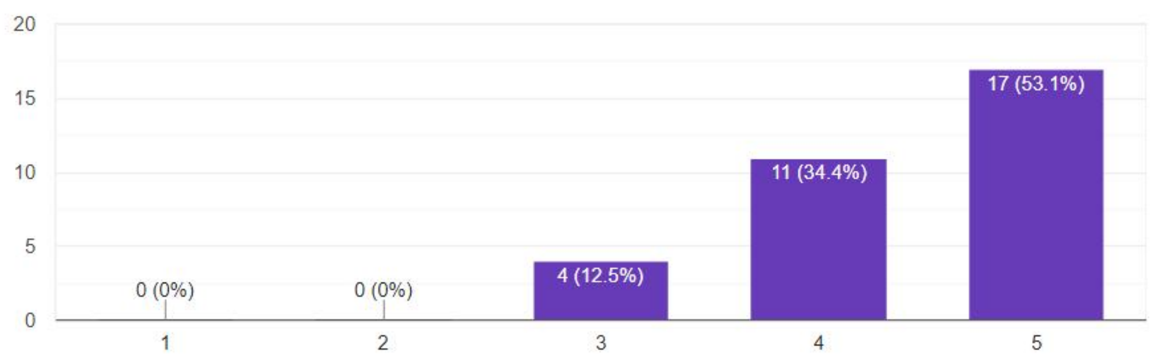
How useful do you think a VR museum would be for learning anatomy/pathology?

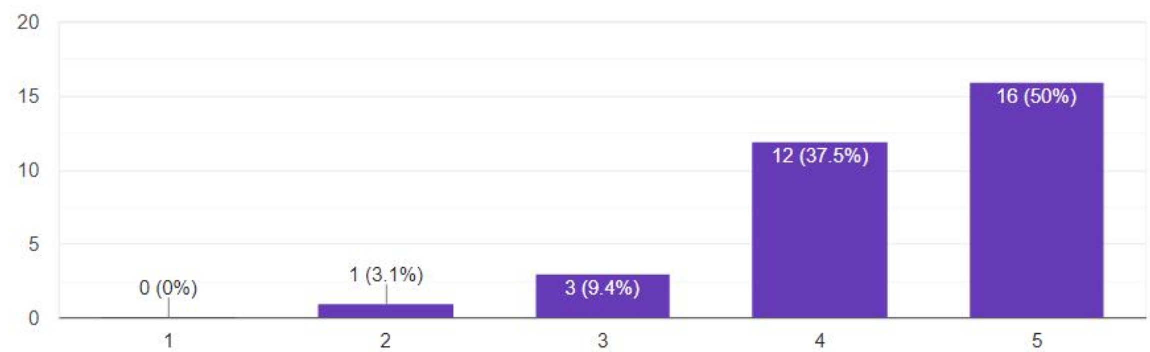
32 responses



Section D: Post-Test Questions (After Using PathoSphere)

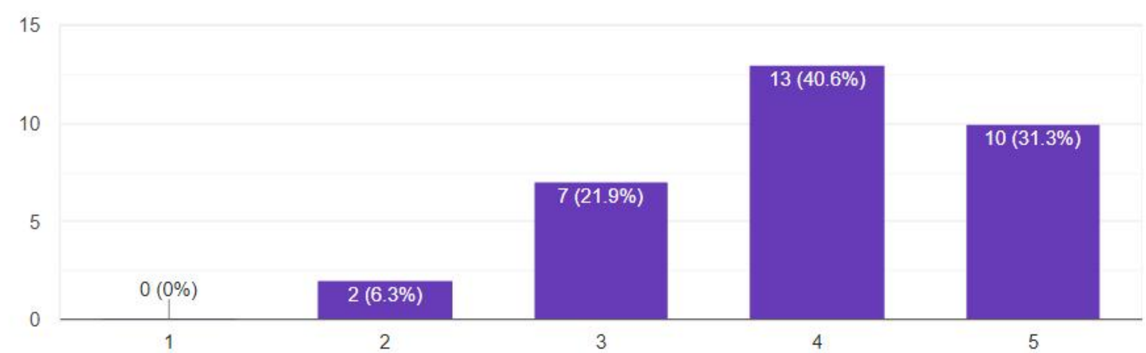
How easy was it to navigate the VR museum?

32 responses



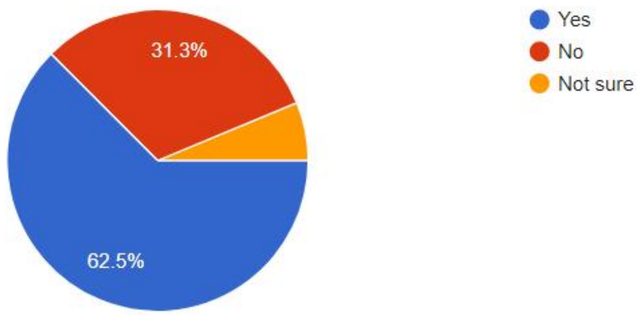
Were the controls intuitive and easy to use?

32 responses



Did you face any discomfort while using the VR headset (e.g., dizziness, eye strain)?

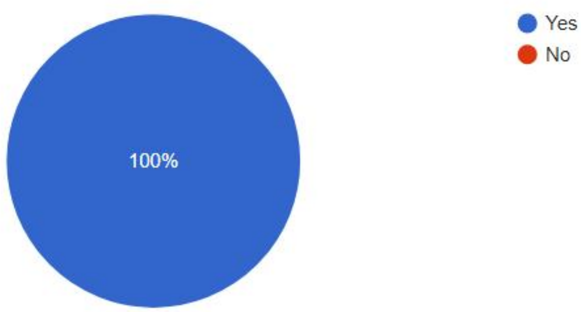
32 responses



Section E: Learning and Engagement

Did PathoSphere help you understand the anatomical structures better?

32 responses



Which part of the VR museum did you find most educational or memorable?

32 responses

organs section

The organ model

The quizzes

Hearing the heart beat on the heart

heart

I like all parts

The interaction

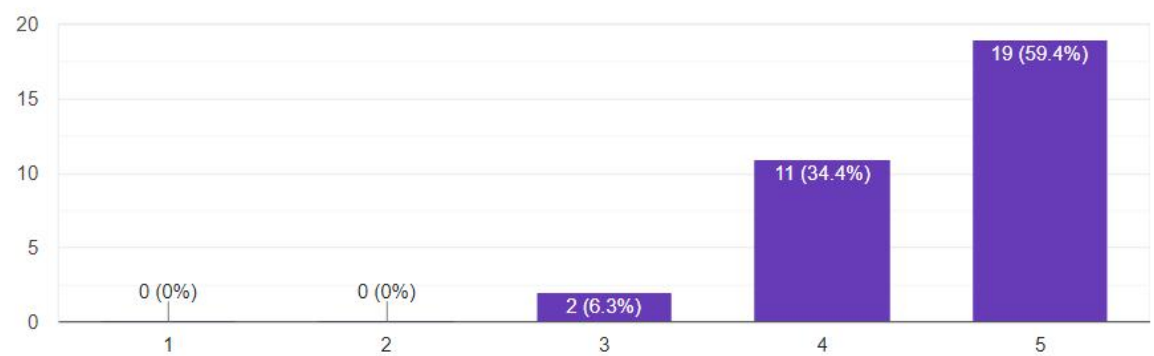
All parts, very interesting and im eager to learn more

Quiz

Copy chart

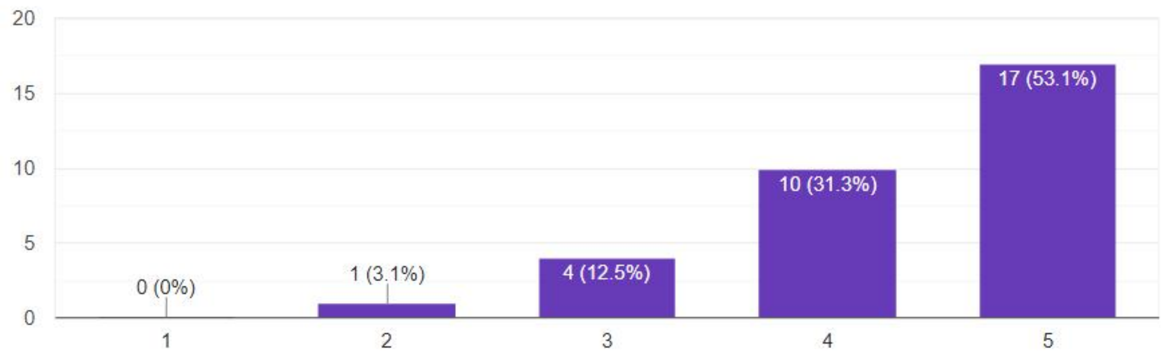
How engaging was the VR experience?

32 responses



How confident do you feel in identifying human organs/pathological features after the session?

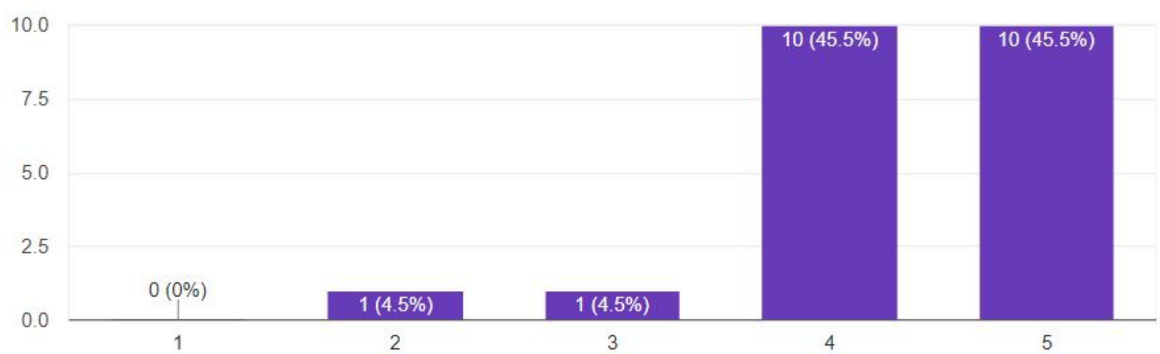
32 responses



Section F: Gamification

If you were to review this system as a game, what score would you give it out of 5?

22 responses



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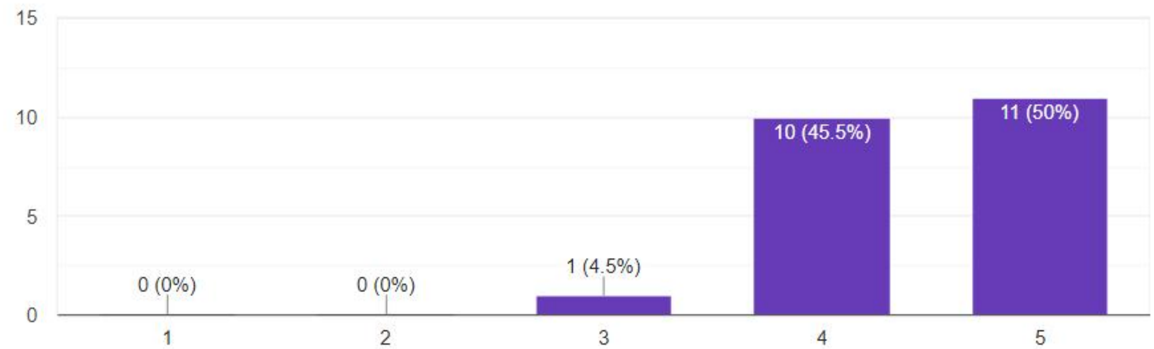
Did the game-like structure (e.g., tasks, progression, simulations) make you more interested in learning about anatomy and pathology?

22 responses



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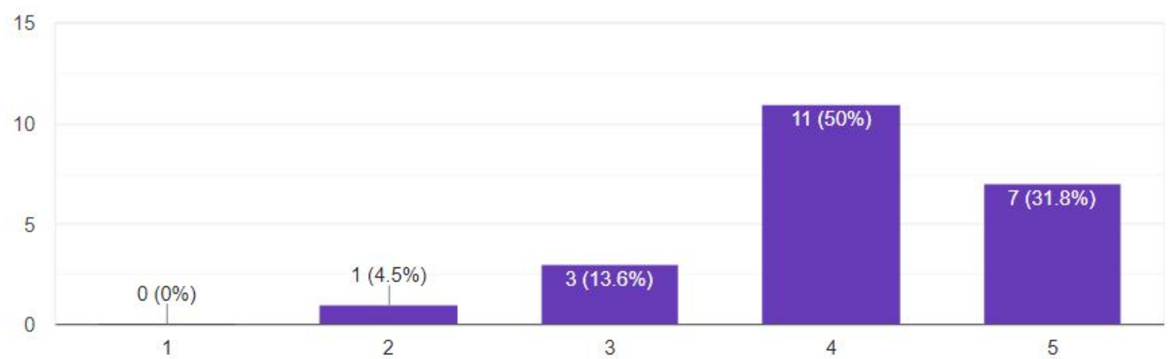
How clear were the instructions and goals for each gamified activity (quizzes, morgue room)?

22 responses



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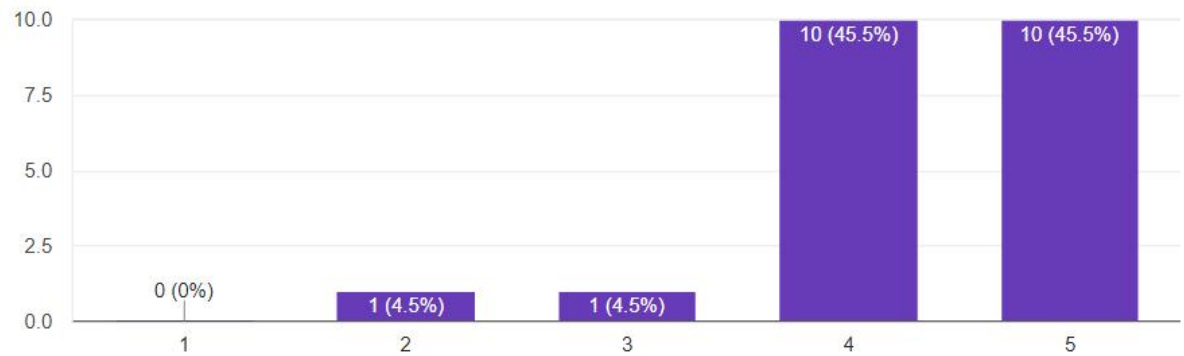
Did the immersive VR environment feel realistic and contribute positively to your learning?

22 responses



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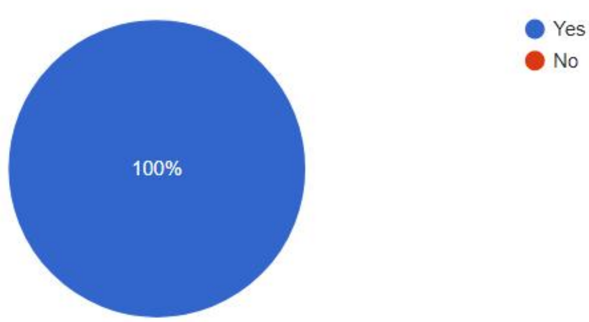
Would you use PathoSphere again to reinforce your learning or explore new content if available?

22 responses



Which gamified feature did you enjoy the most, and why?

20 responses

quiz after section

The morgue room

The Quiz, I learned something new from it.

the quiz section

VR , can hold the model , if can use hand better , 3D

The organ interaction

Interacting with the organ

give dwi bhasa

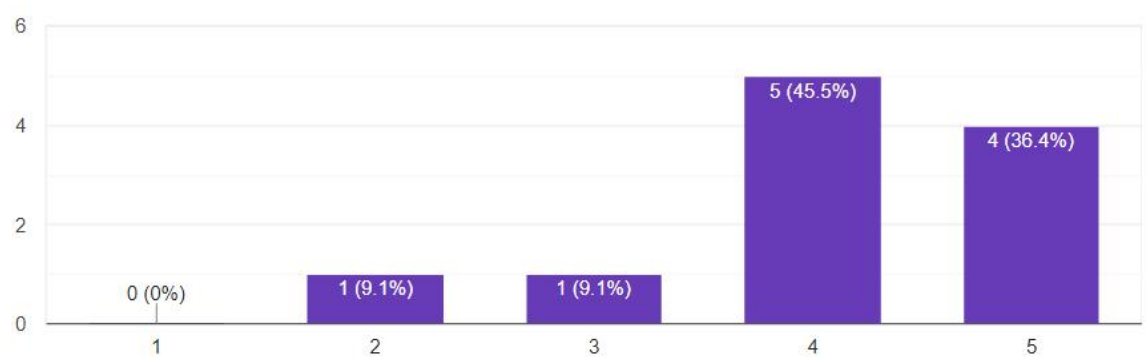
I enjoyed interacting with the quiz, especially dragging the anatomical parts, it made the experience more engaging and fun to complete. In terms of gamified, i liked the leaderboard which motivated me to improve

Evaluate The Usability of ***PathoSphere***

I think that I would like to use this system frequently.

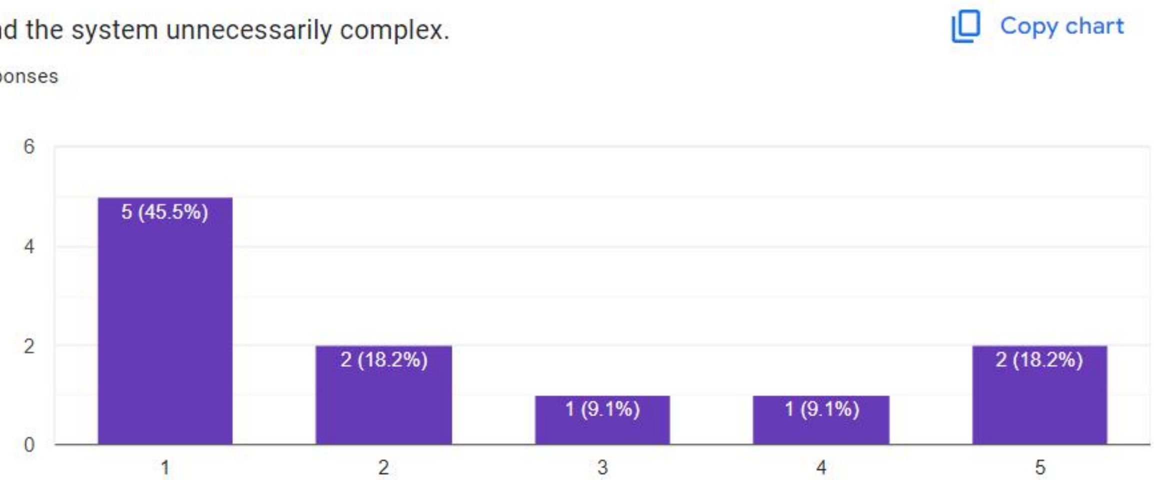
Copy chart

11 responses



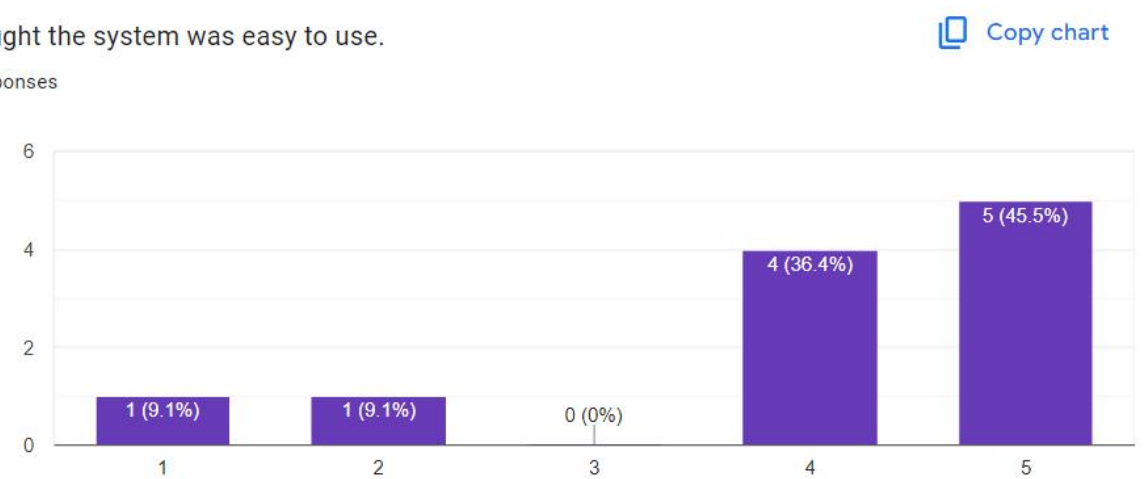
I found the system unnecessarily complex.

11 responses



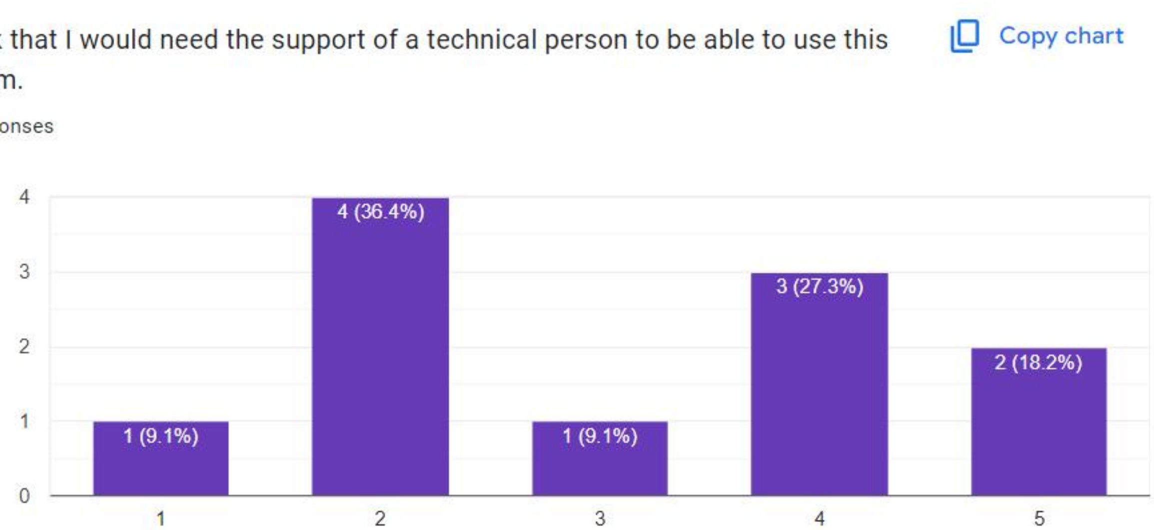
I thought the system was easy to use.

11 responses



I think that I would need the support of a technical person to be able to use this system.

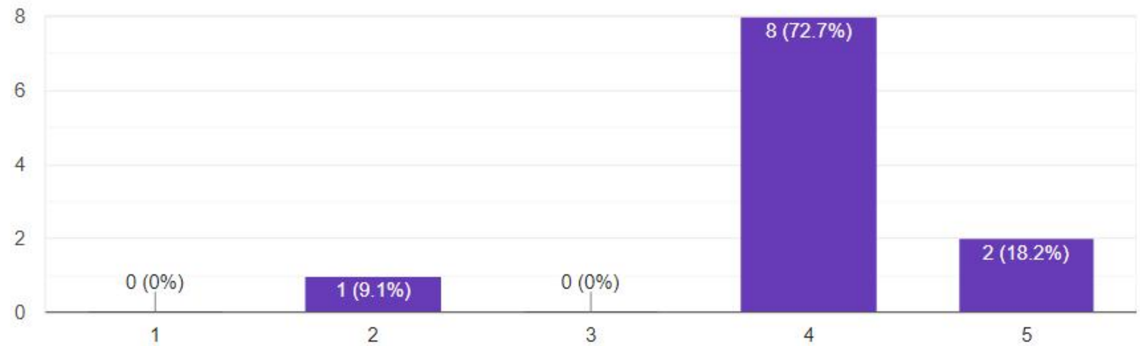
11 responses



I found the various functions in this system were well integrated.

11 responses

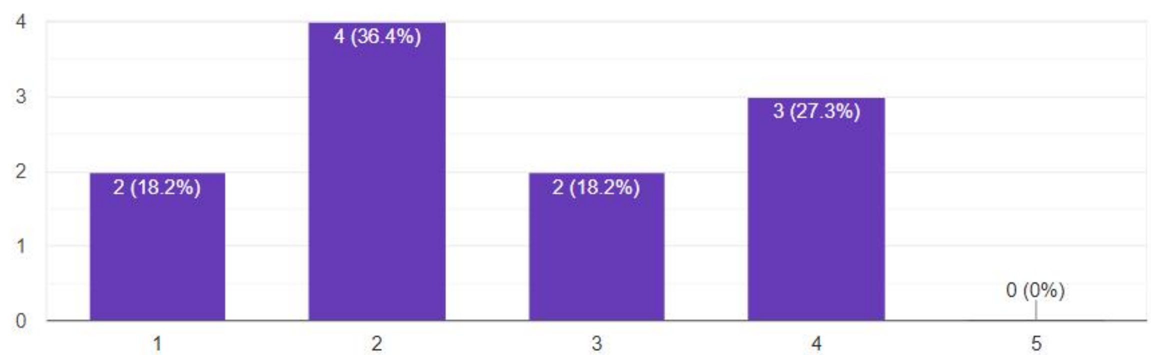
Copy chart



I thought there was too much inconsistency in this system

11 responses

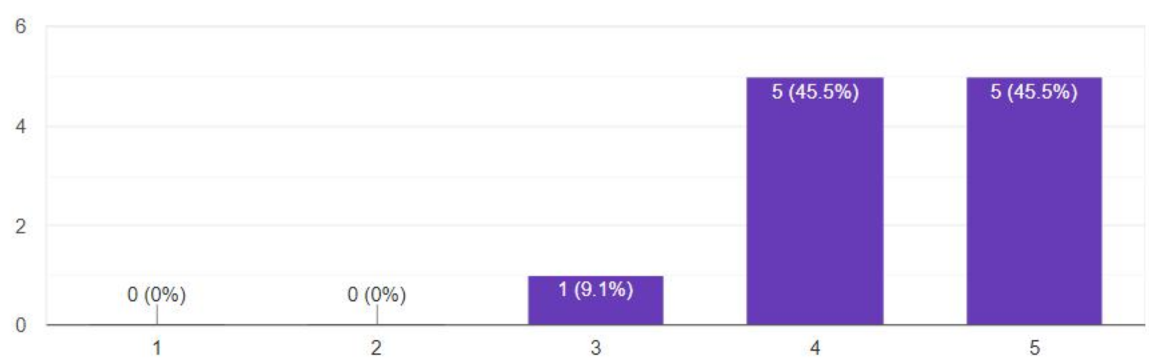
Copy chart



I would imagine that most people would learn to use this system very quickly

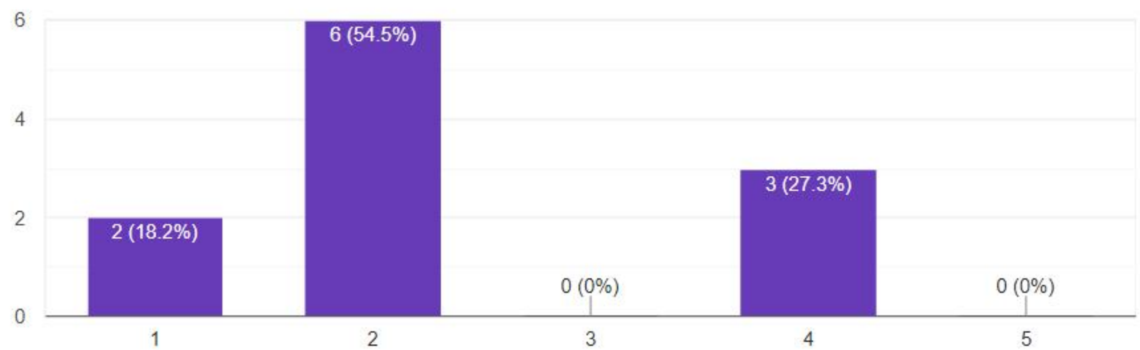
11 responses

Copy chart



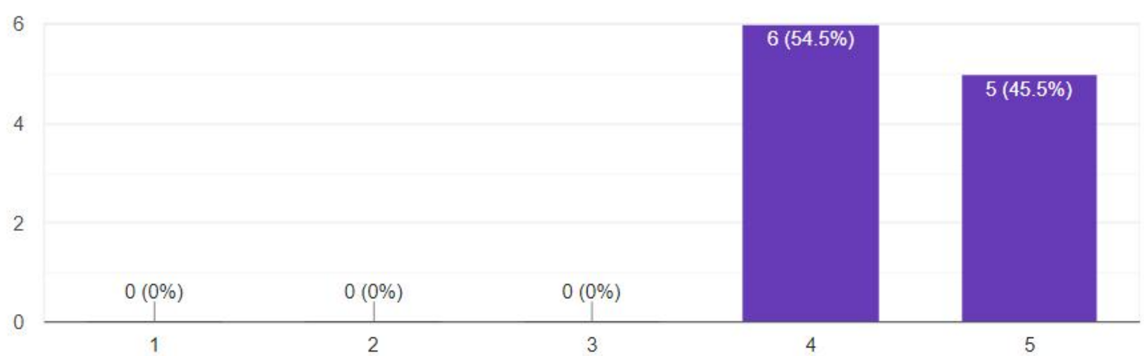
I found the system very cumbersome/difficult to use.

11 responses



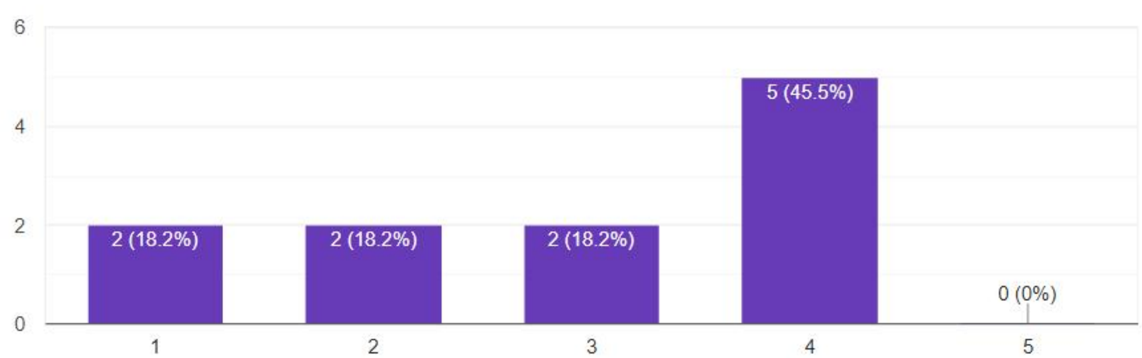
I felt very confident using the system.

11 responses



I needed to learn a lot of things before I could get going with this system.

11 responses



Section G: Feedback

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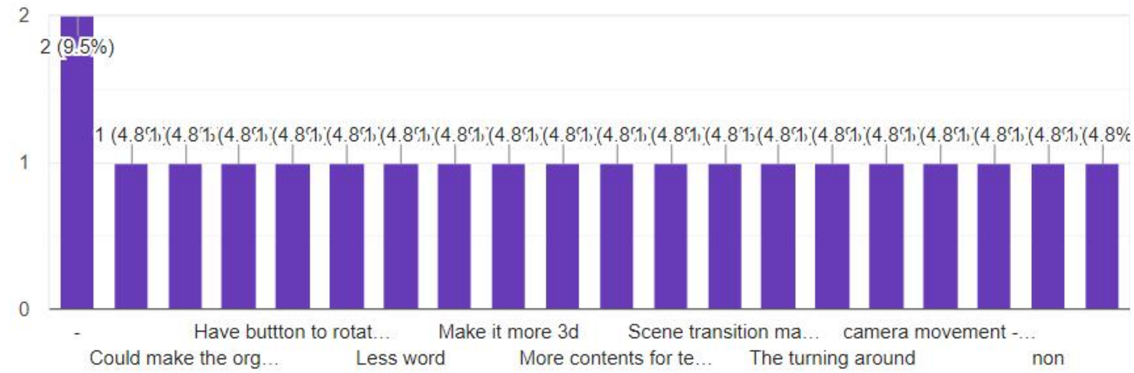
What improvements would you suggest for ***PathoSphere***?

21 responses



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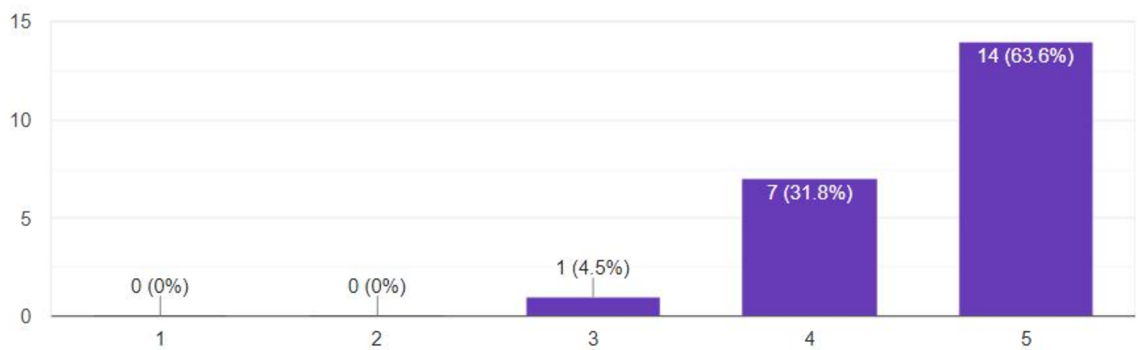
On a scale 1-5, would you recommend this VR museum to other students?

22 responses



Any additional comment

14 responses

-

Very good

I give 6 out of 7

Put more specimen, quiz

Good job

Hope to see more improvement in the system soon. Well done!

None.

Overall, i find it very interactive and i look forward to experiencing it more.

Good luck for your innovation & FYP

APPENDIX D

Survey Testing Hands-On


KELUAR


FCSIT


FCSIT
iCATS


UNIMAS
Infinix NOTE 40X 5G


Infinix NOTE 40X 5G