Design of a Gamification-Based Learning Application on the Human Digestive System for High School Students

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Digestive System Introduction; Gamification; High School Students; Unity

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Abstract

Biology learning at the high school level, particularly on the topic of the human digestive system, still predominantly uses conventional delivery methods that tend to be less interactive. This often makes students quickly lose interest and become less motivated to understand the concepts of the human digestive system. This study aims to develop a gamification-based learning application that integrates game elements such as points, levels, badges, leaderboards, progress bars, and interactive quizzes as an alternative learning medium. The development of this application uses the Multimedia Development Life Cycle (MDLC) method, which includes the stages of concept design, asset creation and design, application implementation using Unity, and functionality testing. In the development process, Unity is used as the main framework for building the Android-based Biology learning application. Unity enables the creation of a more interactive interface with support for animation and three-dimensional visualization while maintaining responsiveness across various gadget screen sizes. Through this approach, Biology learning is expected to become more engaging, interactive, and enjoyable, thereby increasing students' motivation and interest in learning.

1. Introduction

Biology is a continuously evolving science in line with the rapid advancement of science and technology. The fast-paced development of science and technology requires the education sector to improve the quality of its teaching. The quality of education can be enhanced by changing the mindset used as the foundation for curriculum implementation (Surata et al., 2020).

In this context, teachers are required to be able to analyze needs, design, create, develop, and utilize various types of learning resources in accordance with the Regulation of the Minister of National Education (Permendiknas) No. 16 of 2007, by using technology- and information-based biology learning media(Ade Jumita Wulandari et al., 2018).

Based on a preliminary study conducted at SMA Negeri 1 Telukdalam, particularly among 11th-grade students, many students experienced difficulties, especially in creating learning media for presentations such as learning material slides. In addition, students often struggled to stay focused during lessons because the learning

process was monotonous and very limited, leading to decreased motivation and lower learning outcomes (Hatimbarasi Duha Guru SMP Negeri, n.d.).

Based on these issues, this study aims to design an Android-based learning application about the human digestive system by integrating various gamification elements such as levels, badges, leaderboards, progress bars, quiz challenges, and rewards, as well as feedback points after completing quizzes. These elements are designed to enhance motivation, engagement, and provide an enjoyable learning experience for students.

The materials provided in the application include the structure of digestive organs, the function of each organ, and the process of food digestion that occurs in the human digestive system. The content is presented interactively through text, images, animations, and videos to help students better understand the concepts being studied.

A gamification-based quiz is provided at the end of each topic to test students' understanding while offering immediate feedback. With this application, biology learning not only focuses on knowledge transfer but also fosters enthusiasm for learning through a competitive and enjoyable experience. This application is expected to serve as an innovative solution and an effective alternative medium to support biology learning for high school students in the digital era.

1.1 Literature Review

In an effort to enhance the effectiveness of Biology learning through the implementation of gamification, various previous studies have made significant contributions to the development of interactive learning media. These studies serve as important references for understanding how gamification elements can improve students' motivation, engagement, and learning outcomes. By comparing the results of previous research, researchers can gain a deeper understanding of the application of gamification in Biology learning, particularly in the design of a learning application on the human digestive system for high school students.

The first study (Ramli & Nurhidayah, 2024), entitled *"Application of Gamification Strategies to Optimize the Learning Outcomes of Grade XI MIPA 6 Students at SMAN 4 Maros"* by Rani Anggraeni Ramli and Nurhidayah (2024), aimed to determine how the application of gamification strategies could optimize students' learning outcomes on the topic of the excretory system. This study employed the Classroom Action Research (CAR) method, which consisted of two learning cycles, involving 35 students from Grade XI MIPA 6 at SMA Negeri 4 Maros in the 2023/2024 academic year. This research integrated game elements such as awarding points for each learning activity successfully completed by students, providing rewards or recognition for high-achieving students, and implementing group competitions that encouraged interaction and collaboration among students through a point accumulation system. In addition, direct feedback from teachers was applied to provide immediate responses to learning outcomes, along with a leveling system that represented students' gradual learning progress. The implementation of these gamification strategies was proven to significantly enhance students' motivation, participation, and learning outcomes, with a notable increase in learning mastery.

The second study (Eka Febryana et al., n.d.) conducted by Noor Eka Febryana and Zubaidah (2022), entitled *"Implementation of Gamification-Based Assessment Media on Biology Learning Motivation of MAN Kotawaringin Timur Students,"* aimed to determine students' learning motivation levels and the effect of implementing gamification-based assessment media on Biology learning motivation. This study employed a pre-experimental method with a One-Group Pretest-Posttest design and involved 120 11th-grade social science students at MAN Kotawaringin Timur as research samples. The gamification media used included platforms such as Quizizz, Kahoot!, and Wordwall, which were applied during the Biology assessment stage. These platforms provided interactive educational game features such as rankings, flipcards, point systems, timers, and various quiz types, making the evaluation process feel like playing a game. With engaging visuals, interactive questions, and an automatic scoring system, the gamification-based assessments provided immediate feedback to students and created a fun and competitive learning environment. The results indicated a significant increase in students' learning motivation after the implementation of the gamified assessments.

The third study (Kajian Pendidikan IPA et al., n.d.)conducted by Hasna Latipah Sakinah, Aqilatun Ni'mah, Imroatus Sulthoniyah, and Dita Arisona (2025), entitled *"Science-Gamification: Forms of Gamification and Their Implementation in Science Learning,"* aimed to identify and map the types of gamification and their implementation in Science (IPA) learning. This study employed a scoping review method by analyzing ten scientific articles published between 2015 and 2024. The results of the review showed that gamification in Science learning can be divided into two main categories: digital application-based gamification and student activity-based gamification. Application-based gamification includes the use of mobile apps, interactive websites, and online quiz platforms such as Kahoot!, Genially, and Android-based educational games to enhance students' motivation and engagement. Meanwhile, student activity-based gamification includes physical games, simulations, board games such as *Monopoly* and *Snakes and Ladders (Science Edition)*, as well as role-playing methods that promote social interaction and direct engagement.

The fourth study (Prayitno Y S et al., 2020)conducted by Yusuf Syahril Prayitno, Muchamad Arif, Prita Dellia, Etistika Yuni Wijaya, and Ariesta Kartika Sari (2023), entitled *"Development of an Android-Based Educational Game for Biology on the Circulatory System for Grade XI Science Students at the High School Level,"* aimed to develop and test the feasibility of an interactive Android-based educational game to enhance high school students' interest in learning. This study employed the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). The developed educational game integrated gamification elements such as points, levels, direct feedback, and progress evaluation to create an engaging and interactive learning environment.

The fifth study (Anang Kukuh Adisusilo, 2019)conducted by Anang Kukuh Adisusilo (2019), entitled *"Serious Game-Based Thematic Learning for Elementary School Students,"* discussed the development of the serious game concept as a thematic learning medium for elementary school students. This study aimed to create a learning medium that integrates elements of fun and interactivity into the learning process, enabling students to be more motivated and better understand the material. The developed system consists of two main databases: a graph asset repository containing visual assets such as 2D/3D images, audio, and video, and thematic content material containing the lesson content and practice exercises. The serious game concept was designed for both Android and web platforms and equipped with augmented reality (AR) features, allowing students, teachers, and parents to interact directly with the learning content anywhere. Interactive elements such as game scenarios and gameplay were structured according to the theme and objectives of each thematic book to align with school learning methods.

The sixth study (Lisana, 2022)conducted by Lisana (2022) examined the use of interactive 3D animation in the Biology learning process on the topic of the human skeletal structure. The learning application was developed using Unity and designed to allow students to interact directly with 3D models of human bones. This study employed a quasi-experimental method with two groups: a control group that learned using textbooks and an experimental group that used the 3D application.

2. Research Methods

This study used the Multimedia Development Life Cycle (MDLC) development method proposed by Luther (1994). The MDLC method is a research and development approach that focuses on a systematic process for building multimedia products, whether for educational, informational, or interactive purposes. The method aims to produce multimedia products that are effective, engaging, and tailored to user needs through structured development stages. The stages of the MDLC method include concept, design, material collecting, assembly, testing, and distribution.

In this study, the Multimedia Development Life Cycle (MDLC) was applied to produce a Biology learning product that is relevant to students' needs. The concept stage is the initial phase, aimed at determining the purpose of development, target users, application type, and the benefits to be achieved. The design stage focuses on creating the product concept as a foundation for further development. The obtaining material stage involves collecting all necessary resources, such as images, text, audio, video, and animations. The assembly

stage combines all materials into the software according to the design. Next, the testing stage evaluates the functionality and feasibility of the product. Finally, the distribution stage is the last step, where the product is delivered or disseminated to users.

Concept

The concept stage is the initial step in developing a learning application, aimed at defining the basic idea, objectives, and target users. At this stage, it was determined that the application to be developed is a gamification-based educational game that combines adventure and interactive quiz-based learning as a Biology learning medium on the topic of the Human Digestive System.

The main goal of designing this application is to increase high school students' motivation and engagement in learning, particularly for the human digestive system topic, which is often considered difficult due to the numerous biological terms and sequential processes that must be understood. By applying gamification concepts, learning is transformed into an enjoyable activity with game elements such as levels, points, badges, leaderboards, progress bars, and immediate feedback.

The target users of this application are 11th-grade high school students as the primary users, and Biology teachers as learning facilitators. This application is expected to serve as an interactive alternative learning medium that helps students gradually understand the functions and processes of digestive organs while creating a more active and meaningful learning environment.

Game Flow

The game flow/flowchart is designed to provide a comprehensive overview of the gameplay from start to finish. The game flow serves as a visual map that helps developers, designers, and other stakeholders understand how each feature and mechanism in the game is interconnected.

Fig 2.1 illustrates the workflow of the gamification-based Human Digestive System learning application, designed using a progressive game concept (unlock system). The process begins at the "Start" node, which then displays the main menu containing options such as "Start Adventure," "Leaderboard," and "Exit." If the user selects Leaderboard, the system displays a ranking list of students based on the total points earned. If Exit is selected, the application closes and returns to the initial stage.

When the user chooses Start Adventure, the system displays a map of the digestive organs consisting of several levels, from the mouth to the anus. Players must select an available organ level. If the selected level is locked, the system displays a message "Complete the Previous Level" as a progression restriction mechanism. Once the level is unlocked, the user is directed to the organ quiz interface, which contains interactive questions about the functions and processes of digestion.

During the quiz stage, the system checks the answers for correctness. If correct, the player earns points; if incorrect, a brief explanation of the correct answer is provided as educational feedback. After completing all questions in that level, the user can claim the rewards obtained, and the system automatically unlocks the next level. This process repeats until all organ levels are completed.

After completing all levels, the user proceeds to the final quiz, which contains summary questions covering all digestive organs. At the end of the game, the system displays the final results and achievement badges, indicating the player's ability category based on the total score earned.

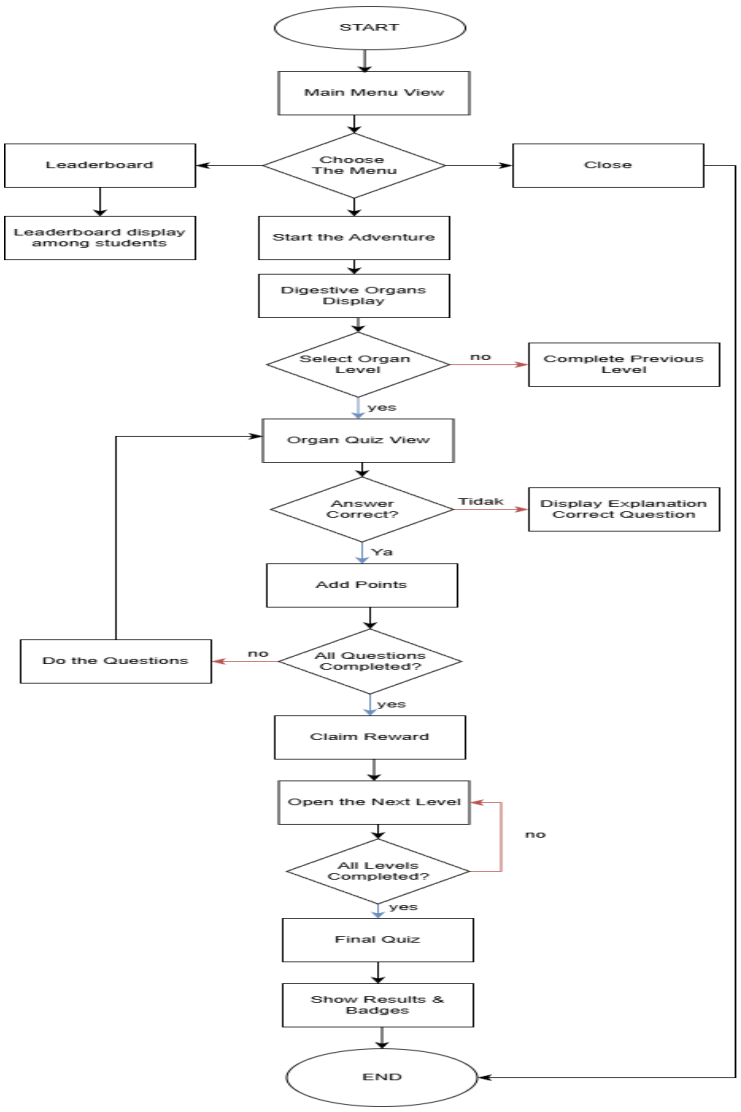

Fig 1. Game Flow

Use Case Diagram

In the context of this study, the use case diagram was specifically developed for the application "Design of a Gamification-Based Human Digestive System Learning Application for High School Students." The main purpose of this diagram is to clearly illustrate the services or functions that users (students) can access and utilize while interacting with the application.

The diagram shows how students, as the primary actors, participate in the learning process through game elements, including logging in, selecting organ levels, answering quizzes, and receiving final results and rewards (badges). The use case diagram also highlights the role of teachers as supporting actors, who have the authority to manage student data, set quiz questions, and monitor final learning outcomes.

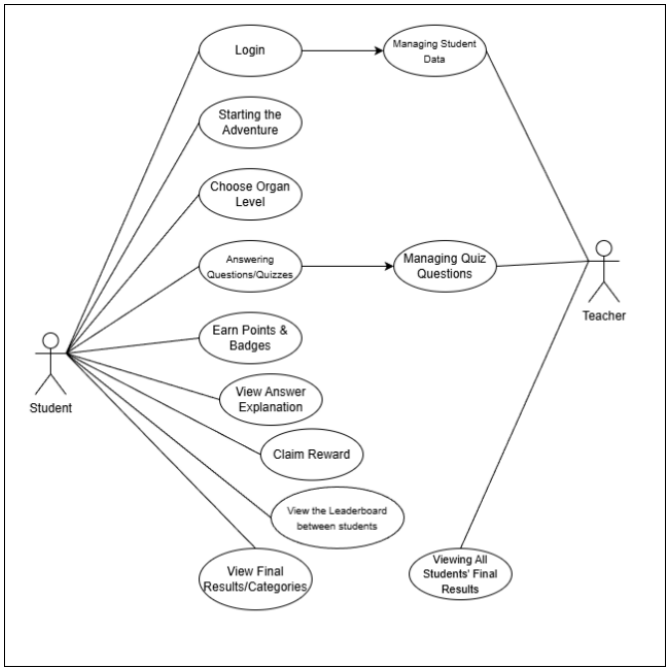

Fig 2. Use Case Diagram

As shown in Fig 2 Students are the primary users of the application, functioning as both players and learners. Students can log in to access the application and connect with user data managed by the teacher. After logging in, students can choose to start the adventure, which displays a map of the digestive organs as the game flow.

Students can then select organ levels according to the sequence that has been unlocked (unlock system). At each level, students answer questions or interactive quizzes about the functions and processes of the digestive organs. Upon completing a level, students can claim rewards. Additionally, students can view the leaderboard to see their ranking and compare their achievements with other users.

Meanwhile, the Teacher acts as the system manager. The teacher can manage student data for monitoring purposes and manage quiz questions used in the game. Teachers also have access to view the final results of all students as a basis for evaluating learning outcomes.

Activity Diagram

An activity diagram serves to visually illustrate the workflow of activities within a system, particularly the interaction between users and the application in performing specific features. This diagram models the sequence of activities, decision-making points, process branching, and relationships between system components in a systematic manner.

In the context of this study, the activity diagram is used to depict the login and registration process, starting from when the user opens the application, successfully logs in, or registers an account, and finally accesses the main application page, as shown in Fig 3. The activity diagram also helps minimize potential errors by providing a clear and systematic representation of the steps that need to be followed.

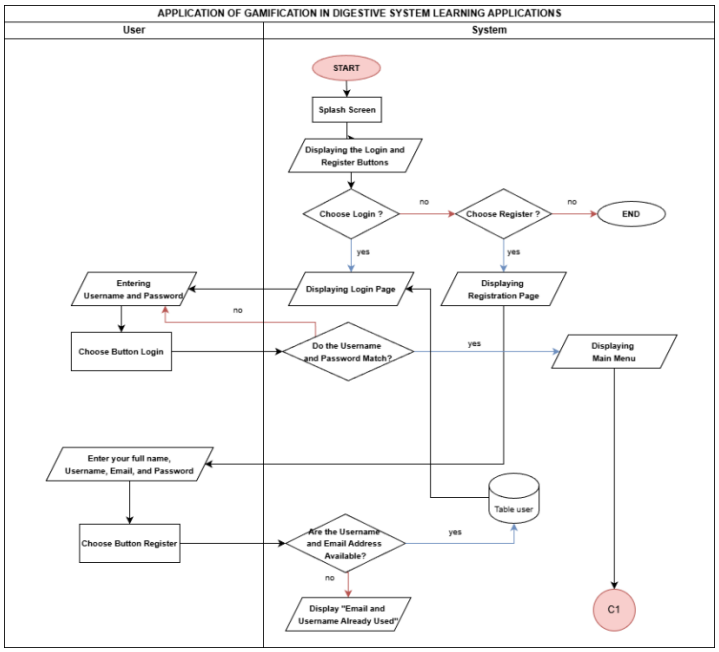

Fig 3. Activity Diagram of the Digestive System Application (Part 1)

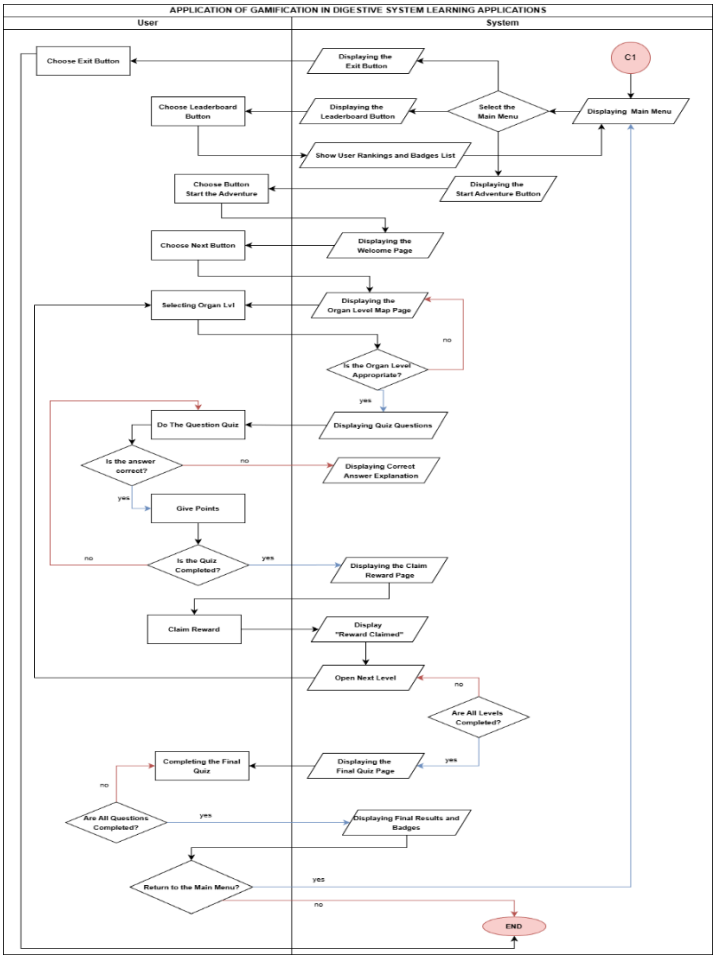

Fig 4. Activity Diagram of the Digestive System Application (Part 2)

Fig 4 illustrates the second part of the activity diagram, explaining the various features available in the application, such as learning materials, quizzes, the leaderboard, and quiz feedback provided after users complete all challenges.

The process begins at the main menu, which contains three options: Start Adventure, Leaderboard, and Exit. If the user selects Leaderboard, the system displays a ranking list of students along with the badges earned. If Exit is chosen, the application closes. When the user selects Start Adventure, the system displays a welcome page and a map of the digestive organ levels. Users can only access levels that are available according to their previous progress. Each level contains interactive quizzes that provide points as rewards for correct answers, while incorrect answers trigger explanations to reinforce understanding. After completing all questions in a level, users can claim rewards and unlock the next level. Finally, users take the final quiz, covering all materials. The final results display the total points, achievement category, and badges earned.

Material Collecting

The material collecting stage aims to gather all the necessary materials and components required for the application's development to ensure a smooth implementation in the next stage. In this study, the primary materials collected were Biology learning content on the topic of the Human Digestive System, sourced from the *Biology Elective Book for Grade XI SMA/MA, Curriculum 2013 Revised 2017*, as well as various scientific journals and educational references in Biology.

The purpose of collecting these materials is to ensure that the learning content presented in the game aligns with the national curriculum and the learning outcomes applicable at the high school level. Each digestive organ is developed as a learning unit within a game level, with each organ containing distinct educational content. The materials cover organ functions, mechanical and chemical digestion processes, enzyme roles, and the interrelationships between organs within the human digestive system.

This stage also includes the preparation of interactive quiz questions for each game level. The questions are designed based on the basic competency indicators for Grade XI Biology, covering knowledge aspects (C1–C3) and conceptual understanding (C4). The question types developed include multiple-choice and true/false, accompanied by immediate feedback that provides explanations for incorrect answers, allowing learning to continue even within the context of the game. The question bank is adjusted according to the difficulty level of each game level.

Table 1. Design of Quiz Questions in the Game

Level/Organ	Question	Correct Answer	Feedback
Level 1 – Mouth	What is the main function of the amylase enzyme in the digestive process in the mouth?	Converting starch to maltose	The amylase enzyme only works on carbohydrates, not proteins or fats.
	True/False: Saliva helps digest fat.	False	Saliva only helps digest carbohydrates through the amylase enzyme, not fats.
Level 2 – Esophagus	The process of moving food from the mouth to the stomach is called	Peristaltic	Peristalsis is the movement of smooth muscles in the esophagus to push food into the stomach.
	True/False: In the esophagus, chemical processes occur by enzymes.	False	There are no chemical processes in the esophagus, only mechanical peristaltic movements.
Level 3 – Stomach	The following substances play a role in killing bacteria in the stomach:	Hydrochloric acid (HCl)	Hydrochloric acid lowers the pH and kills bacteria that enter with food.

Level/Organ	Question	Correct Answer	Feedback
Level 4 – Small intestine	True/False: The lipase enzyme functions to digest protein.	False	The lipase enzyme works to break down fat into fatty acids and glycerol.
Level 5 – Colon	The main function of the large intestine in the digestive system is	Absorbs water and forms feces	The large intestine functions to absorb water from food waste and form feces.
Level 6 – Anus	The main role of the anus in the digestive system is	Place for excretion of digestive waste (defecation)	The anus functions as the final channel for excreting feces.
	True/False: The sphincter muscles in the anus play a role in regulating the excretion of feces.	True	The sphincter muscles work to open and close the anal canal reflexively and consciously.
Final Quiz (Final Stage)	A combination of all levels of the digestive organs (10 random questions).		The final result determines the achievement category: "Needs More Learning," "Great Digestor," or "Digestive System Expert."

In addition to the learning materials, various multimedia assets supporting the game's visuals and interactivity include:

1. 3D models of human digestive organs, used to create a realistic three-dimensional visual environment.
2. Images, icons, and navigation buttons for the user interface (UI).
3. Background music and sound effects, enhancing the immersive experience of the game.

3. Result and Discussion

The application was developed using Unity 3D with C# to manage game logic, user interactions, and gamification. The project structure includes Assets (3D organ models, icons, audio, texts), Scripts (point system, quiz validation, level transitions, feedback), and Scenes (login, main menu, level map, quizzes, and results).

Login Page

This scene functions as the entry gateway to the system, where users must undergo an authentication process before accessing the main features of the application. On this page, users are required to enter their username and password in the provided fields.

Fig 5. Login Page

Welcome Page

This scene displays the welcome screen of the learning application, *"Human Digestive System Adventure."* It serves as an introduction before users enter the main menu of the game. At the top, the text "Welcome to the Human Digestive System Adventure!" greets users and introduces the main theme of the game. An illustration of a school-aged character wearing a uniform and carrying a backpack represents the player as a student ready to learn and embark on the adventure. A speech bubble containing images of digestive organs provides a visual context for the material to be studied. Additionally, a green "NEXT" button at the bottom allows users to proceed to the main menu of the application.

Fig 6. Welcome Page

Main Menu

This scene serves as the starting interface of the application once users have successfully logged in or registered. The main menu functions as the primary gateway for users to select various activities within the game.

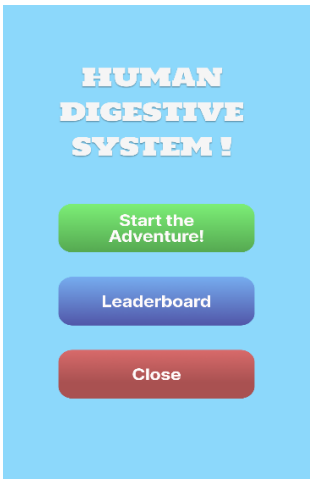

Fig 7. Main Menu

Level Map

This scene displays an interactive map representing the pathway of the human digestive system. Each organ is shown as an icon that functions as a level button for the user to select and access the corresponding game level.

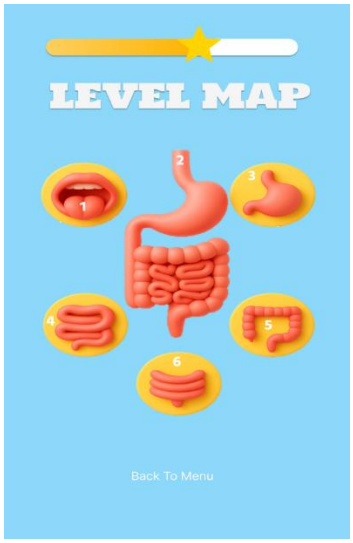

Fig 7. Level Map

Players can only access organs (levels) that have been unlocked according to their learning progress. Level 1 begins with the mouth and will unlock the esophagus once the player successfully answers all quizzes in theprevious level. This concept is called the Unlock System, which challenges players to continue to the next stage. In addition to organ icons, the map also displays a progress bar at the top of the screen to indicate how far the player has completed the game. The main goal of this scene is to foster curiosity, motivation, and learning enthusiasm through visual elements that resemble an educational adventure.

Scene Quiz

This scene serves as the core of the gameplay. In this scene, users interact directly with the 3D digestive organs and answer interactive quizzes related to the functions and digestive processes of each organ.

At each level, players are presented with interactive quiz questions consisting of multiple-choice and true/false items, based on Grade XI elective Biology material relevant to the functions and processes of the digestive organs. The system provides immediate feedback after each response: correct answers earn points along with a success animation, while incorrect answers trigger a brief explanation of the correct answer as a form of corrective learning. All points earned are automatically accumulated and displayed in the corner of the screen to motivate players to achieve the highest score.

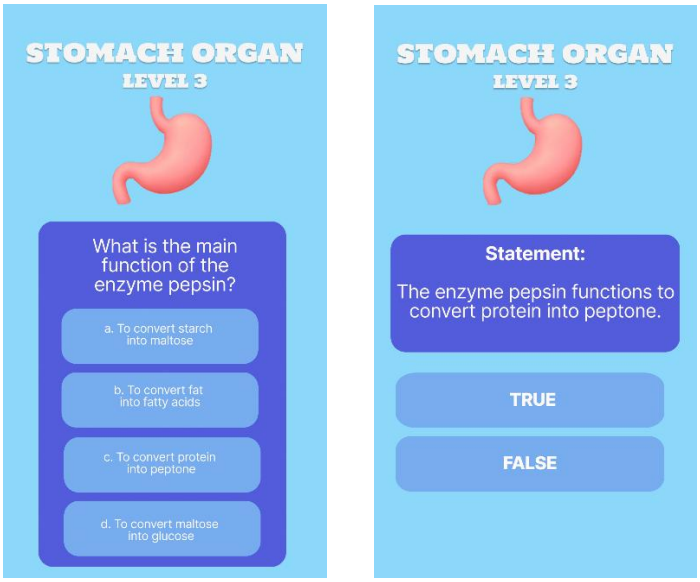

Fig 8. Scene Quiz

Result Scene

This scene represents the final part of the game, displayed after players successfully complete one or more levels. It serves as a reward and motivational tool, allowing players to assess their understanding of the material they have studied.

At this stage, players receive feedback on their achievements after completing a specific level. This display acts as a form of appreciation for their success, fostering a sense of accomplishment and encouraging them to continue playing. Additionally, buttons such as “Back to Menu” function as a transition to return to the main menu and continue the gaming experience.

Fig 9. Scene Points and Badges

This section displays the final score, which is the total accumulation of points from all quizzes completed. Players also receive digital badges or trophies as recognition for specific achievements, such as the "Digestive System Expert", awarded based on their success rate and total points earned.

Additionally, a leaderboard is available, showing the highest-ranking students based on their scores. The scene also provides navigation buttons such as Repeat Level, Back to Main Menu, and Next Level, allowing players to easily restart or continue the game. Based on the final results, the system categorizes players' abilities into three levels: "Needs More Study" (0–50 points), "Skilled Digester" (51–80 points), and "Digestive System Expert" (81–100 points).

Testing

1. Internal Testing (Black Box Testing)

Testing was conducted by the developer using the Black Box Testing method to ensure that each main feature functions according to the design. The following are the testing results:

Table 2. Test Results Black Box Testing

No	Tested Feature	Expected Result	Testing Result	Status
1	Main Menu Navigation	Buttons work and switch between scenes correctly	All buttons function properly	Passed
2	Level System (Unlock System)	New levels unlock after previous ones are completed	Levels open sequentially according to progress	Passed
3	Quiz Feature	Points increase for correct answers and feedback shown for incorrect ones	Point and feedback systems work well	Passed
4	3D Display and Animation	Animations and audio are synchronized	Animations run smoothly without errors	Passed
5	Leaderboard and Progress Bar	Scores are stored and displayed in correct order	Rankings appear automatically	Passed
6	Login System	Valid accounts can log in, invalid ones are rejected	Login validation works properly	Passed

Result: All features function as expected without critical errors or bugs.

2. User Testing (User Experience Evaluation)

User testing was conducted on 20 students from grade XI of senior high school as the main target users. Evaluation used a Likert scale (1–5) to assess ease of use, visual quality, interactivity, learning benefit, and motivation.

Table 3. Test Result User Experience Evaluation

Evaluation Aspect	Indicator	Average Score	Category
Ease of Use (Usability)	Ease of navigation and understanding of instructions	4.6	Excellent
Visual & Interface Design	Quality of 3D visuals, colors, and icons	4.7	Excellent
Interactivity	System response and quiz engagement	4.5	Excellent
Learning Benefit	Helps understanding of the human digestive system	4.8	Excellent
Motivation & Gamification	Game elements (points, badges, leaderboard) enhance learning motivation	4.9	Excellent

Overall average score: 4.7 (Excellent category).

3. Testing Analysis

Based on the internal and user testing results, it can be concluded that:

1) The application runs without functional errors and meets the design requirements.

2) The 3D visuals and gamification elements significantly increase students' learning motivation.

3) Users reported that the application is easy to use, interactive, and effective in helping them understand the digestive system material.

The testing results show that the human digestive system learning application based on gamification is suitable for use as an alternative learning medium. Gamification elements successfully create an engaging, interactive, and effective learning experience for high school students.

4. Conclusions

This study concludes that the development of a gamification-based learning application on the human digestive system can effectively enhance student motivation, engagement, and understanding of biological concepts. By integrating gamification elements such as points, levels, badges, leaderboards, and feedback systems, the learning process becomes more interactive and enjoyable.

The application developed using Unity 3D and C# successfully provides a visually appealing and functional learning environment aligned with the high school biology curriculum. Testing results show that the system runs smoothly, meets user needs, and supports active learning through interactive quizzes and progressive challenges.

For future research, it is recommended to expand the content to other biological topics, integrate more advanced gamification features such as adaptive difficulty and multiplayer modes, and conduct broader user testing to evaluate long-term learning impacts.

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