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GAMIFICATION OF A DIGITAL SNAKE AND LADDER GAME BASED ON LIFE SCORE FOR ADOLESCENT TUBERCULOSIS EDUCATION

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Abstract

Tuberculosis (TB) remains a public health problem in Indonesia, particularly among adolescents with relatively low health literacy and limited access to engaging educational media. Conventional educational approaches tend to be less effective in increasing adolescent engagement and understanding of TB prevention and spread behaviors. This study aims to design and implement a gamification-based digital snakes and ladders game as a TB education medium for adolescents by integrating a life score algorithm to represent user health behaviors. The research method used is research and development with the stages of needs analysis, system and gamification design, prototype development, and initial testing. The game was developed using web-based technology with active and passive box mechanisms containing TB educational content, as well as a reward and penalty system using ladders and snakes. The results showed that the game prototype was successfully implemented according to the design, where the life score algorithm was able to dynamically depict changes in healthy and risky behaviors during the game. The integration of gamification elements also allows for the delivery of TB educational materials interactively and contextually. This study concludes that the gamification-based digital snakes and ladders game has the potential to be an effective alternative educational medium in increasing adolescents' understanding of TB prevention and spread.

Keywords: Gamification; Digital Snakes and Ladders Game; Tuberculosis Education; Teenagers; Life Score.

INTRODUCTION

Tuberculosis (TB) remains one of the major public health challenges at both the global and national levels. According to the Global Tuberculosis Report 2024, Indonesia is among the countries with the highest TB burden in the world, ranking second after India, with an estimated more than one million new cases each year [1]. This high disease burden indicates that TB control efforts are not yet fully optimal and still require continuous strengthening, particularly through promotive and preventive approaches that are effective and adaptive to the characteristics of target groups. At the national level, the Indonesia Health Profile 2023 shows that TB is one of the leading causes of death from infectious diseases, with a significant incidence rate among the productive age group [2]. Adolescents are included in this group and have a relatively high vulnerability to TB transmission due to behavioral factors, social environment, and limited understanding of disease transmission mechanisms and prevention. Therefore, adolescents represent a strategic target group for health education interventions to support sustainable TB control.

However, conventional health education approaches that primarily rely on lectures and printed media are often less effective in reaching adolescents who are already familiar with digital technology. These limitations result in low levels of engagement and learning motivation, causing health messages to be delivered suboptimally [3]. This condition highlights the need for alternative educational approaches that are more interactive, participatory, and aligned with the characteristics of the younger generation. With the advancement of information technology, gamification and game-based learning approaches are increasingly being applied in health education. Gamification utilizes game elements such as challenges, feedback, and reward systems to enhance user motivation and engagement, while serious games are specifically designed for educational purposes and promoting health behavior

change [4], [5]. This approach is considered relevant for adolescents as it provides an enjoyable yet meaningful learning experience. Various recent studies indicate that gamification-based eHealth interventions have significant potential to improve user engagement, motivation, and learning outcomes. Systematic reviews report that gamification is effective in encouraging active participation and promoting health behavior change across different target groups [3], [5]. In addition, serious games have been widely used as health education media for adolescents, including for health promotion, infectious disease prevention, and improving health literacy [6], [7].

Several empirical studies also show that digital educational games can positively impact adolescents' knowledge, attitudes, and health behaviors compared to traditional educational methods [8], [9]. In the context of infectious diseases, digital health technologies have been evaluated as supportive approaches in tuberculosis control, particularly in health education, improving disease literacy, and strengthening preventive behaviors based on risk awareness [10], [11]. Furthermore, research on gamification and game-thinking in health education demonstrates that feedback mechanisms, simulations, and reward systems within games can reinforce the learning process and users' conceptual understanding in a sustainable manner [12]–[14].

Nevertheless, the use of gamified digital board games for the education of chronic infectious diseases such as TB remains relatively limited. Most previous studies have focused on general digital health applications or serious games for specific health topics, without integrating adaptive game mechanisms capable of dynamically representing users' health behaviors during gameplay [13], [15]. Moreover, digital game-based TB education specifically targeting adolescents is still rarely found in the scientific literature, indicating a research gap that needs to be addressed. Based on this gap, this study aims to design and develop a gamified digital snake and ladder game as a TB educational medium for adolescents by integrating a life score algorithm. The contributions of this study include: (1) the development of an interactive and contextual digital game-based TB education medium, (2) the implementation of a life score algorithm as a representation of players' health behavior within the game mechanics, and (3) the enrichment of scientific literature related to the application of serious games and gamification in infectious disease education, particularly TB, among adolescents.

METHOD

This study employs a research and development (R&D) method focusing on the development of a gamification-based digital educational game to deliver tuberculosis (TB) information to adolescents. This method was chosen because the study aims to produce a product in the form of a digital snake and ladder game that is designed, implemented, and functionally tested as a health education medium. The game system was developed using web-based technology with a client–server architecture to support game data management. The gameplay mechanism adapts the traditional snake and ladder concept into a digital format by implementing active and passive tiles containing TB educational content. Active tiles are used to present TB information, representations of TB-related behaviors, and evaluative questions, while passive tiles function as part of the gameplay flow without triggering additional content. Furthermore, reward and penalty mechanisms are implemented through ladders and snakes to represent healthy and risky behaviors.

The integration of gamification in the game is supported by the implementation of a life score algorithm as an evaluation indicator representing users' health behavior responses during gameplay. The life score is updated based on user interactions with the educational content presented, so that the game score is not only determined by the pawn's progress but also by user engagement with TB-related materials. The research stages were carried out systematically as follows:

(1) needs analysis, including the identification of functional game requirements and the determination of TB educational content to be integrated into the gameplay mechanism;
(2) system and gamification design, including the design of the digital snake and ladder board, determination of active and passive tiles, reward and penalty mechanisms, and the design of the life score algorithm;
(3) development of the digital game prototype by integrating the user interface, game logic, and web-based data management; and
(4) initial functional testing to ensure that all game mechanisms, score updates, and educational content delivery operate according to the design.

Through these stages, this study produces a gamification-based digital snake and ladder game prototype capable of presenting TB educational material in an interactive and contextual manner, with the potential to be used as an alternative educational medium for adolescents.

Model Design (Game Flow and Interaction)

The game model is designed by adapting the snake and ladder concept into a system-based digital game. The gameplay interaction begins when the user accesses the application and enters a game session. Once the game starts, the system displays a digital snake and ladder board consisting of active and passive tiles, a score indicator (life score), and game controls in the form of a virtual dice mechanism. The gameplay flow begins when the user performs a dice roll action. The system automatically calculates the dice value and moves the pawn on the game board according to the result obtained. The pawn's movement is fully controlled by the system until it stops at the destination tile based on the dice outcome.

When the pawn stops on a tile, the system identifies the type of tile. If the pawn stops on an active tile, the system triggers an interactive popup displaying TB educational content, representations of TB-related behavior, or evaluative questions. Conversely, if the pawn stops on a passive tile, the game continues without displaying additional content. User interaction with the displayed popup becomes an integral part of the gameplay flow as it affects subsequent game conditions. User responses, particularly to evaluative question popups, are processed by the system to update the life score based on predefined rules. In addition, reward and penalty mechanisms are implemented through ladders and snakes, which influence pawn movement to specific tiles as representations of healthy and risky behaviors.

The entire gameplay flow, from user actions to system responses, is designed in a structured and consistent manner. To clarify the relationship between the user and the system within the game, the interaction flow model is visualized in the form of a flow diagram illustrating the dice roll process, pawn movement, educational popup triggers, and life score updates. The interaction flow between the user and the system in the digital snake and ladder game is visualized using a UML Activity Diagram as shown in Figure 1.

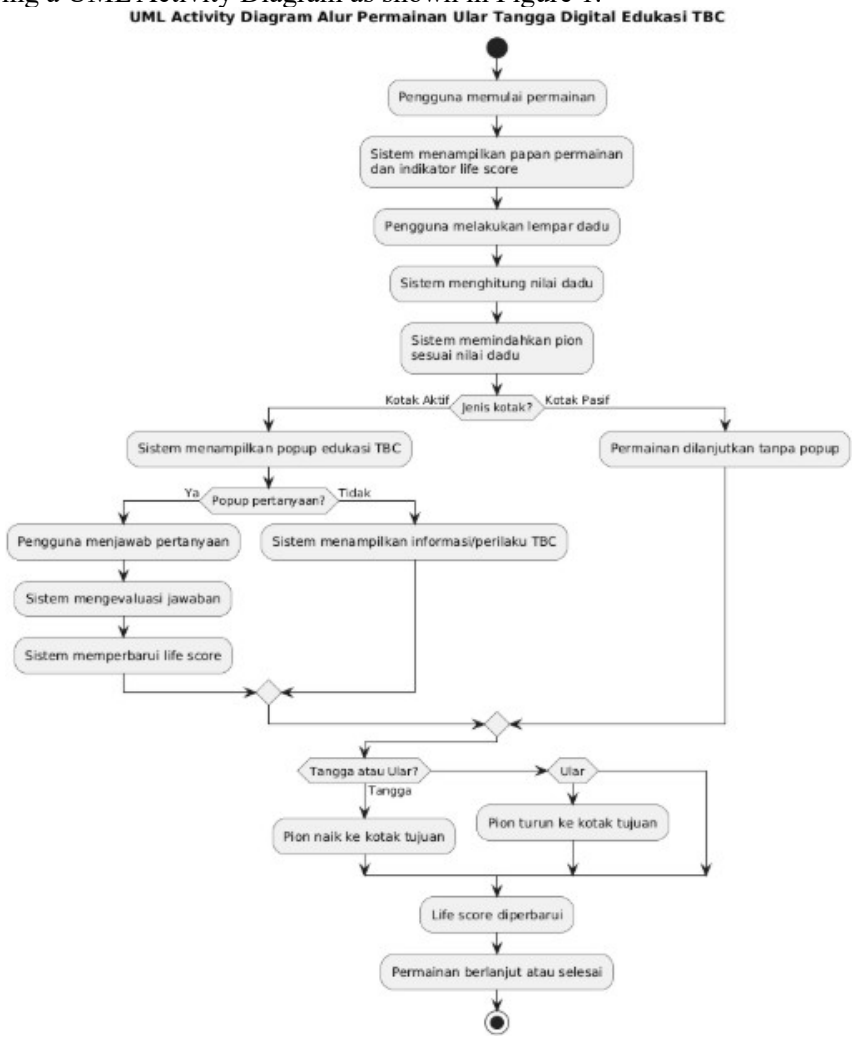

Figure 1. UML Activity Diagram of the TB Education-Based Digital Snake and Ladder Game Flow

Educational Content Integration

The integration of educational content in the game is designed to ensure that tuberculosis (TB) information is delivered contextually and seamlessly within the gameplay mechanism. The educational content is not presented as separate material but is directly embedded into the elements of the digital snake and ladder game, allowing the learning process to occur during gameplay. TB educational content is classified into several types, namely basic information about TB, representations of healthy and risky behaviors related to TB, and evaluative questions. Basic information includes educational messages related to TB prevention, transmission, and control. Behavioral representations are used to illustrate examples of behaviors that support TB prevention as well as behaviors that may increase the risk of transmission. Evaluative questions are designed to measure users' understanding of the material presented.

The delivery of educational content is implemented through active tiles on the game board. When a player's pawn lands on an active tile, the system displays an interactive popup according to the predetermined content type. Information and behavior popups function as educational delivery tools, while evaluative question popups require users to respond as part of the gameplay flow. The integration of educational content is also linked to gamification mechanisms through the implementation of rewards and penalties. Healthy behaviors represented in the game are associated with ladders as rewards, while risky behaviors are associated with snakes as penalties. This approach aims to reinforce educational messages by providing direct consequences to game progress. Through this approach, the integration of TB educational content in the game serves not only as an information delivery medium but also as a tool for shaping behavioral understanding through gameplay experience. This model enables players to learn TB-related material interactively, repeatedly, and contextually without being separated from the main gameplay flow.

Algorithm Design (Life Score Mechanism)

The life score algorithm is designed as the primary evaluation mechanism to represent users' responses and health behaviors during gameplay. The life score functions as an indicator of game achievement influenced by user interaction with TB educational content integrated into the game mechanics. The life score calculation is event-driven, where score updates occur each time the player interacts with educational content on active tiles. These interactions may include exposure to information, behavioral representations, or responses to evaluative questions. Each interaction results in a change in the life score value based on predefined rules.

The life score update is generally formulated as follows:

$$LS_{\{t+1\}} = LS_t + R_t - P_t$$

Where:
LS_t is the life score at the previous game state
LS_{t+1} is the updated life score after interaction
R_t represents the reward obtained from positive user interactions (e.g., correct answers or healthy behaviors)
P_t represents the penalty resulting from negative interactions (e.g., incorrect responses or risky behaviors)

Rewards are assigned when users demonstrate appropriate understanding of TB educational material, particularly in evaluative question popups. Conversely, penalties are applied when users provide responses that do not align with the presented material. The magnitude of rewards and penalties is determined by the game design and applied consistently throughout gameplay. In addition to affecting the score value, changes in the life score are also linked to reward and penalty mechanisms on the game board. Ladders represent positive consequences of healthy behaviors, while snakes represent negative consequences of risky behaviors. Thus, the life score not only influences the numerical score but also contributes to the dynamics of pawn movement within the game. This approach creates an adaptive learning evaluation mechanism, where score achievement is not solely determined by dice roll probability but by the quality of users' cognitive responses to TB educational content. The integration of pawn progression and educational interaction through the life score algorithm enables dynamic and contextual assessment during gameplay. As a result, the system reduces the dominance of chance in conventional gameplay while enhancing the validity of gamification-based learning evaluation without compromising user experience.

System Architecture and Implementation

The architecture of the TB educational game system is designed using a client–server approach to support game data management, user authentication, and centralized storage and processing of scores. This approach is chosen to ensure data consistency, ease of educational content management, and future system scalability.

On the client side, the system is implemented as a web-based game interface accessible through browsers on various devices. The client component is responsible for displaying the digital snake and ladder board, dice roll animations, pawn movements, educational popups, as well as life score and game progress information. All user interactions, such as dice rolls and responses to educational content, are initially processed on the client side before being sent to the server. The server side functions as the manager of system logic and game data. It handles user authentication, game data storage, life score updates, as well as recording final scores and leaderboard data. In addition, the server stores and manages TB educational content displayed on active tiles, allowing content updates without modifying the client side.

Communication between the client and server is carried out through web-based data exchange mechanisms, where requests from the client are sent to the server and responded to with data used to update the game state. This mechanism ensures consistent synchronization of game status, particularly in updating life scores and storing user game results. During implementation, the game system is developed by integrating several main modules, including the user interface module, game logic module, life score calculation module, and data and server management module. The game logic module controls the gameplay flow, including dice rolling, pawn movement, tile identification, and educational popup triggers. The life score calculation module is implemented based on the designed formula, ensuring that every user interaction directly affects the game score. This client–server architecture enables the game system to operate in a structured, modular, and scalable manner. By separating client and server roles, the TB educational game provides a responsive gameplay experience while maintaining data integrity and user evaluation results.

Evaluation Method (Functional Testing)

The evaluation method used in this study is functional testing to ensure that all features and mechanisms of the TB educational game operate according to the system design. Functional testing is chosen because the study focuses on the development and implementation of a digital game prototype, with evaluation directed at the conformity of system functions to the predefined requirements. Testing is conducted using a black-box testing approach, where evaluation focuses on system outputs based on user inputs without considering the internal code structure. Each main game function is tested through usage scenarios representing actual gameplay, from user authentication to storing game results.

The functional aspects tested include:

(1) user authentication process, ensuring the system correctly validates user access;
(2) gameplay mechanisms, including dice rolling, pawn movement, and tile type identification;
(3) triggering and display of TB educational popups on active tiles, including information, behavioral representations, and evaluative questions;
(4) updating and calculation of life score based on user interactions during gameplay; and
(5) storage of final scores and presentation of leaderboard data via the server system.

Each test scenario is evaluated based on the conformity between expected results and actual system outputs. The system is considered to function properly if all features execute without errors, life score values are updated consistently, and game data is stored and displayed correctly on the leaderboard. Through this functional testing, it can be concluded that the gamification-based digital snake and ladder game prototype meets the system's functional requirements and is ready to be used as a digital game-based TB educational medium.

RESULTS AND DISCUSSION

Results

This section presents the results of the implementation of the gamification-based digital snake and ladder game system developed according to the design outlined in the research methodology. The implementation was carried out by integrating the user interface module, game logic, educational content activation mechanism, and life score algorithm within a client–server architecture. The results are analyzed based on their conformity with the predefined functional requirements, system stability, and consistency of integration between modules. In addition, this section illustrates how gamification elements and tuberculosis (TB) educational content are successfully integrated into the gameplay mechanism as a whole. The implementation results are presented systematically through several subsections covering aspects of the interface, game logic, educational content activation, and the life score-based evaluation mechanism.

User Interface and Game Board Implementation

The user interface (UI) of the game was developed as a responsive web-based application that can be accessed via browsers on both desktop and mobile devices. A responsive design approach was applied to ensure display compatibility across various screen resolutions without compromising visual quality or system functionality. The interface design considers usability principles, layout consistency, and visual clarity to suit adolescent users who require a simple, intuitive, and interactive interface. The structure of the main game page is organized into a single integrated display that includes the game board, life score indicator, and dice roll control. The game board is positioned as the central element to maintain user focus, while the score indicator and interaction controls are placed in easily visible and accessible areas. The main interface of the game is illustrated in Figure 2, which shows the integration of the digital snake and ladder board, life score indicator, and dice roll button within a structured visual layout.

Figure 2. Main Interface Display of the TB Education-Based Digital Snake and Ladder Game

The game board consists of 100 tiles arranged numerically from the starting position to the final position. Each tile has a unique identifier on the system side to support event-triggering mechanisms when the pawn stops at a specific position. This identification enables the system to recognize the type of tile (active or passive), trigger educational content, and automatically activate reward or penalty mechanisms according to the game design. The visual implementation of the game board includes representations of ladders and snakes as symbols of health behavior consequences. Ladders are visualized as upward paths representing healthy behaviors in the context of tuberculosis (TB) prevention, while snakes are visualized as downward paths representing risky behaviors. This visual representation functions not only as a gameplay element but also as a conceptual symbol that reinforces educational messages through a metaphorical approach. Active and passive tiles are managed on the system side. Active tiles function as triggers for educational content, while passive tiles serve only as part of the game movement flow without triggering additional interactions. The classification of tile types is not fully displayed explicitly to users in order to maintain an element of exploration and enhance engagement during gameplay. Pawn movement animation is implemented sequentially based on the dice roll result, allowing users to visually track game progress. In addition, the life score indicator is displayed in real time and updated immediately after user interaction with

educational content. This instant feedback mechanism supports gamification principles that emphasize direct system responses to user actions. This integrated interface implementation demonstrates that visual elements and gameplay mechanisms are not designed separately but instead work together to create a contextual and interactive learning experience. Testing results show that the system interface operates responsively and stably, with no significant delays in pawn movement, content triggering, or life score updates. This indicates that the integration between the interface module and game logic functions as intended according to the system design.

Game Logic and Dice Mechanism Implementation

The implementation of game logic is designed to ensure that all user interaction flows operate systematically and are integrated with the designed educational mechanisms. The game logic module serves as the main controller that manages dice rolling, pawn movement, tile type identification, educational content activation, and the application of reward and penalty mechanisms based on game conditions. The dice rolling mechanism is implemented using a Random Number Generation function with a value range of 1 to 6. The generated value serves as the main parameter in determining the number of steps the pawn moves. Pawn movement is processed sequentially, allowing users to visually monitor game progress. This approach is chosen to enhance interactive engagement and maintain consistency in the gameplay experience.

After the pawn reaches its final position based on the dice result, the system automatically identifies the attributes of the tile through an identifier matching process in the database. Each tile is classified as a regular tile, educational tile, positive behavior tile, negative behavior tile, or interactive quiz tile. This identification process forms the basis for determining the system's subsequent response to the user. The implementation of reward and penalty mechanisms is represented through ladders and snakes. Ladders symbolize healthy behaviors that positively impact game progress, while snakes represent risky behaviors that result in position reduction or score decrease. This mechanism not only influences gameplay but also reinforces educational messages through simulation of health behavior consequences.

Interactive quizzes are integrated as a form of formative evaluation to measure users' understanding of the provided material. The system automatically validates user-selected answers and differentiates responses based on accuracy. If the user selects the correct answer, the system provides positive feedback along with a brief explanation to reinforce conceptual understanding. Conversely, if the selected answer is incorrect, the system still displays the correct answer along with a conceptual explanation related to the material. For example, in a question regarding tuberculosis transmission mechanisms, if the user selects an incorrect option, the system provides clarification that tuberculosis is transmitted through the air when an infected person coughs or sneezes, releasing droplets containing bacteria. This mechanism ensures that errors are not merely recorded as failures but are also utilized as learning opportunities through a corrective feedback approach. Figure 3 illustrates the implementation of the dice rolling mechanism, activation of educational content, display of positive and negative behaviors, and interactive quizzes within a single gameplay cycle.

Figure 3. Implementation of game logic, educational content activation, rewards, penalties, and interactive quizzes

Functional testing results show that the distribution of dice values consistently occurs within the specified range, the pawn movement process is stable without conflicts between events, and content activation occurs according to the designed box classification. The integration of game logic and educational mechanisms demonstrates that each user interaction not only affects game progress but also contributes to experiential learning. Thus, the game logic module successfully supports the integration of entertainment and educational aspects in the developed system.

Life Score and Educational Evaluation Mechanism

The life score mechanism was developed as a quantitative indicator to represent the user's level of engagement and understanding during the game. Unlike conventional scoring systems that only reflect the progress of a game's position, the life score in this system is designed to be directly integrated with the user's educational interactions. Unlike conventional snakes and ladders systems, which rely entirely on dice roll probabilities, the life score model in this study integrates the user's cognitive evaluation into the game mechanism. Conceptually, the cumulative score calculation can be expressed as:

$$Life\ Score = \sum(Rt) - \sum(Pt)$$

Where Rt represents the accumulated rewards from correct educational responses, while Pt represents the accumulated penalties resulting from inappropriate responses or exposure to risky behaviors in the game. This model places cognitive performance as the primary variable in determining the final score. The life score is displayed in real time on the game's main interface and is automatically updated based on the user's responses to the educational content and interactive quizzes. Each correct answer adds to the score, while an incorrect answer does not add to the score or, under certain conditions, can reduce the score, such as when the player lands on the risky behavior box (the snake symbol). Thus, changes in the score represent a direct consequence of the quality of the user's interaction with the TB material.

This approach adopts gamification principles that integrate elements of feedback, rewards, and penalties into the learning process. Immediate score updates allow users to instantly reflect on their performance. This mechanism not only increases motivation to play but also strengthens the association between actions and consequences, thus supporting the development of deeper conceptual understanding. In addition to being an indicator of individual progress, the life score also serves as a formative evaluation tool within the system. Scores earned during the game reflect the user's level of success in understanding the material on tuberculosis prevention and transmission. Thus, the system not only passively presents information but also continuously measures learning outcomes.

The integration of the life score, quiz mechanism, and snake and ladder symbols forms an experiential learning cycle. Users perform actions (answer questions or land on certain squares), receive feedback in the form of score changes, and receive conceptual explanations that reinforce understanding. This cycle occurs repeatedly throughout the game, supporting the gradual internalization of the material. Test results show that life score updates occur stably without system delays. Scores accumulate consistently according to user interactions, and no inconsistencies are found between quiz evaluation results and score updates. This indicates that the learning evaluation mechanism is well integrated into the developed game logic and structurally reduces the dominance of luck in determining game outcomes.

System Testing and Functional Validation

System testing was conducted to ensure that all designed functions in the digital snake and ladder game based on tuberculosis education operate according to system requirements specifications. Testing focused on functional aspects, game logic stability, and the consistency of integration between the educational module and the gamification mechanism. The testing method used was black-box testing, where evaluation is based on the correspondence between user input and system output without directly analyzing the code structure. This approach was chosen because the research focused on validating system functionality from a user perspective. Tests were conducted on several key system components, namely the dice roll mechanism, pawn movement, box type identification, educational content activation, quiz answer validation, and life score updates. Each component was tested based on a predetermined usage scenario.

The functional testing results are shown in Table 1.

Table 1. System Functional Test Results

No	Test Scenario	Input	Expected Output	Result
1	Dice roll	Click the dice roll button	System displays a number from 1–6	Success
2	Pawn movement	Dice value = 4	Pawn moves 4 steps	Success
3	Ladder tile	Pawn lands on a ladder tile	Pawn moves up to the target position	Success
4	Snake tile	Pawn lands on a snake tile	Pawn moves down to the target position	Success
5	Quiz activation	Pawn lands on a quiz tile	Question is displayed	Success
6	Correct answer	Select correct answer	Score increases & explanation is displayed	Success
7	Incorrect answer	Select incorrect answer	Score does not increase & clarification is shown	Success

Based on the test results, all scenarios produced outputs consistent with the system design. No functional errors or inconsistencies were found between user inputs and system responses. The integration mechanism between game logic, educational content, and the evaluation system operated synchronously without conflicts between events. In addition to functional testing, display compatibility testing was also conducted across various screen resolutions on desktop and mobile devices. The results showed that the interface remained responsive without layout distortion or significant delays during interaction processes. Overall, the validation results indicate that the system meets the designed functional requirements and is capable of running the integration between gameplay and learning aspects in a stable manner. Therefore, the system is suitable for use as a game-based educational medium in the context of tuberculosis prevention.

Discussion

The results of system implementation and testing show that the tuberculosis education-based digital snake and ladder game successfully integrates game elements with learning mechanisms in a systematic and structured manner. The integration of game logic, interactive quizzes, reward and penalty mechanisms, and the life score indicator forms an experiential learning ecosystem, where user interaction directly influences the evaluation process and reinforcement of the material. Previous research in health gamification generally focuses on increasing user motivation and engagement as the primary indicators of success in digital interventions. Although this approach is effective in improving engagement, most systems still maintain gameplay mechanisms that are not fully integrated with learning evaluation.

In contrast, the system developed in this study integrates real-time cognitive evaluation through a life score mechanism that is updated based on user responses to TB educational content. Rewards and penalties do not merely function as gameplay elements but are directly associated with representations of healthy and risky behaviors, ensuring that each interaction carries measurable educational consequences. Thus, score achievement is not solely determined by dice roll probability but also by the quality of users' cognitive responses to the presented material. This approach reduces the dominance of chance in conventional gameplay and enhances the validity of gamification-based learning evaluation. The representation of ladders as symbols of healthy behavior and snakes as symbols of risky behavior provides a metaphorical and contextual visualization of consequences. This visualization strengthens users' understanding of cause-and-effect relationships between actions and their impact on health, helping them build more concrete conceptual understanding compared to conventional one-way information delivery methods.

The interactive quiz mechanism, supported by corrective feedback, further strengthens the knowledge internalization process. Immediate feedback allows users to quickly correct conceptual errors and understand the reasoning behind correct answers. The integration of instant feedback and life score updates creates a repetitive and adaptive learning cycle, where cognitive performance directly influences game dynamics. From a technical perspective, functional testing results show that all system modules operate according to specifications without significant errors. The stability of dice rolling, pawn movement, educational content activation, and score updates reflects the consistency of the client–server architecture used. The separation between interface modules and system logic enables flexible content management without disrupting the main game structure, thereby supporting future scalability.

However, this study has several limitations. The evaluation conducted is still limited to functional system testing and does not yet include quantitative measurement of user knowledge improvement through pre- and post-intervention designs. In addition, statistical analysis of user engagement and satisfaction on a larger scale has not yet been performed. Therefore, further research is needed to empirically test the system's effectiveness through experimental approaches and more comprehensive quantitative analysis. Overall, this study demonstrates that

integrating gameplay mechanisms with a life score-based learning evaluation system has significant potential as an adaptive and measurable digital health education model. This model can serve as a conceptual framework for developing serious games for other health topics that require interactive, contextual, and cognitively evaluated learning approaches.

Limitations

This study still has several limitations. First, the developed system is still at the prototype stage and has not been tested on a larger population scale. Second, the effectiveness of learning has not been measured using quantitative instruments such as pre-test and post-test to empirically assess knowledge improvement. Third, long-term behavioral changes related to TB prevention have not been analyzed longitudinally. Future research is recommended to conduct experimental trials using a quasi-experimental design to measure the impact of health literacy improvement more significantly.

CONCLUSION

This study successfully designed and implemented a gamified digital snake and ladder game system based on a life score mechanism as an educational medium for tuberculosis (TB) among adolescents. The developed model integrates reward and penalty mechanisms with real-time cognitive evaluation, making the gameplay not only recreational but also educational and adaptive to user responses. The results of functional testing on 10 main system scenarios show a 100% success rate, where all functions—including dice rolling, pawn movement, educational content activation, quiz answer validation, life score updates, as well as score storage and display—operate according to the predefined design specifications. The integration between the user interface module, game logic, interactive quiz mechanism, and life score algorithm runs consistently and stably within a client–server architecture. This mechanism enables structured score updates and game data management without disrupting the user's gameplay experience.

The main contribution of this study lies in the development of a learning evaluation model based on a life score algorithm that is directly integrated with gameplay mechanisms. This approach structurally reduces the dominance of chance factors in conventional games and strengthens the role of cognitive performance in determining game outcomes. Thus, the developed system functions not only as an educational entertainment medium but also as a measurable learning evaluation instrument in the context of health education. However, this study is still limited to the development and functional testing stage of the prototype. Quantitative evaluation of learning effectiveness through experimental designs, such as pre- and post-intervention measurements, has not yet been conducted. Therefore, future research is recommended to examine the system's impact on improving health literacy and behavioral change empirically on a larger scale. Overall, the proposed life score-based gamification model has strong potential as a conceptual framework for developing interactive, adaptive, and cognitively evaluated serious games for health education.

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