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Enhancing Learning Applications for Clinical Decision Support Through Gamification Design

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ABSTRACT — In the learning process, learning media supports the delivery of educational material to students. Implementing gamification enriches educational media and enhances student engagement. This research developed e-learning media for clinical decision support systems (CDSS) material. In the medical field, CDSS is well established and integrated into education as part of the curriculum. CDSS is a computerized system aiding decision-making in diagnosing and treating diseases. In the educational domain, CDSS courses are offered to clinical and nonclinical students. The application was developed using a feature-driven development method and incorporated gamification elements like rewards, challenges, and leaderboards through MDA frameworks. The development process began with the overall design of the application and the determination of learning objectives, followed by the integration of gamification elements aligned with the application's design. The development included application design, gamification elements, functionality, usability, and user experience testing aspects. The final product is an Android application. Functionality testing using black box testing achieved 100% suitability. User testing was conducted using the system usability scale (SUS) and the user experience questionnaire (UEQ). The results showed an average SUS score of 74.9, indicating good usability, and the UEQ score was rated "Excellent." These findings demonstrate that incorporating gamification in CDSS learning enhances the application's supporting features. Gamification elements such as rewards, challenges, and leaderboards are expected to attract learners and encourage active participation in the learning process. CDSS learning applications have the potential to increase motivation and engagement, creating an interesting and effective learning experience for individuals from various backgrounds.

KEYWORDS — Gamification, Learning Application, Clinical Decision Support System, Motivation.

I. INTRODUCTION

A clinical decision support system (CDSS) is a computer system designed to assist in effective and efficient decision-making for diagnosing and treating diseases, patient care, and managing healthcare institutions [1], [2]. The clinical decision support system (CDSS) integrates informatics and medical knowledge utilizing a technological framework to collect, manage, and analyze health information.

In the educational domain, both clinical and nonclinical educational backgrounds, delivering this course requires a specialized approach. Students and medical personnel often struggle to understand and practically apply CDSS concepts due to the lack of interactive, application-focused learning resources. To enhance CDSS learning, effective media that emphasizes practical application is needed.

Learners need effective media to understand concepts, skills, and competencies. E-learning tools, such as mobile apps and online platforms, offer high levels of interaction and engagement. The flexibility to learn without time and place constraints has been enhanced through accessible formats on computers, tablets, and smartphones. One effective strategy to maintain learners' interest is gamification, which incorporates game elements like points, levels, challenges, and rewards to foster active engagement. This approach motivates learners to complete tasks by utilizing a points system, challenging levels, and rewards for achievements [3]. By incorporating game elements like point systems to motivate achievement, levels to provide gradual challenges, and rewards to recognize success, learners feel more motivated to engage with and complete learning tasks [4].

This paper presents the design and implementation of gamification in a CDSS learning application. The structure of the paper is as follows: Section II covers the fundamental concepts and potential benefits of gamification in educational media. Section III outlines the research methodology. Section IV presents the research findings and discussion. Finally, Section V concludes the paper.

II. OPPORTUNITIES FOR GAMIFICATION IN CDSS LEARNING

A clinical decision support system (CDSS) is a computer system designed to influence clinical decision-making at the point of care [1]. It integrates medical science and informatics, utilizing computational algorithms to generate medical decisions based on individual medical records.

Learning media convey instructional information during the educational process [5]. These media play a strategic role in teaching and learning, making the choice of media crucial for learning outcomes. E-learning, which uses information technology such as computers, laptops, or smartphones connected to the internet, allows access to learning materials, interaction with instructors and peers, and the completion of assignments and exams online [6].

Gamification is an approach that uses game elements to address problems outside the gaming domain [7], [8]. It incorporates elements like points, leaderboards, and badges into nongame contexts to increase user engagement [9]. The concept includes products, mindsets, processes, experiences, designs, and systems that use game elements. Initially, gamification emerged from features designed for entertainment and to attract user interaction. Gamification in applications is expected to provide experiences and motivation similar to playing a game [10].

The concept of gamification originates from entertainment games, which are designed to attract and engage users. Over time, games have also been developed for educational purposes to motivate users. Consequently, the concept of gamification emerged as a tool to solve various problems. The evolution of game science is illustrated through the development of gamification.

Gamification has proven to be a popular strategy for effectively increasing learning interest and motivation [9]–[12]. According to several studies, the proper implementation of gamification can enhance students' engagement and motivation in the learning process.

Gamification offers a valuable opportunity to enhance medical education by incorporating game elements into the learning process. These elements, such as rewards, challenges, and simulations, foster engagement and motivation among learners. Gamification enables learners to apply theoretical knowledge in practical scenarios, thereby improving understanding and retention. It also introduces healthy competition, instant feedback, and personalized learning paths that accommodate diverse learning styles.

In the medical field, gamification promotes risk-free healthcare decision-making, distance learning, learning analytics, and rapid feedback [13]–[15]. Medical education is evolving rapidly as students possess high technological literacy and seek diverse educational experiences. As a result, technology-enhanced active learning models and multimedia educational tools are being integrated into the curriculum [13]. Today, most university students belong to Generation Z, a group closely associated with technology. Innovations in learning media significantly impact the knowledge transfer process [16]. Research on the role of gamification in medical education has been extensive [17]–[21]. Additionally, gamified medical education facilitates skill development, critical thinking, and decision-making in a safe, interactive environment. Gamification can enhance learning, engagement, and cooperation in real-world applications.

III. METHODOLOGY

Design planning was conducted using the activity-centered design (ACD) method. ACD, which is an evolution of human-computer interaction (HCI) design, employs a contextual approach and considers user behavior motivation in system development [22]. This research focused on the core activity of CDSS learning. Gamification development was carried out regularly according to the planned activities. This method synergized with application development through feature-driven development. ACD aided in understanding users and their needs for feature planning within feature-driven development. Both approaches were based on a comprehensive mechanics, dynamics, and aesthetics (MDA) gamification framework that emphasized player experience.

This research comprises three main stages: gamification design and implementation, development, and testing. The design stage employed the ACD method, utilizing the MDA gamification framework. The development stage followed the feature-driven development method. In the testing stage, black box testing was conducted to assess the application's functionality, along with SUS and UEQ evaluations to gauge user experience. The research flow is illustrated in Figure 1.

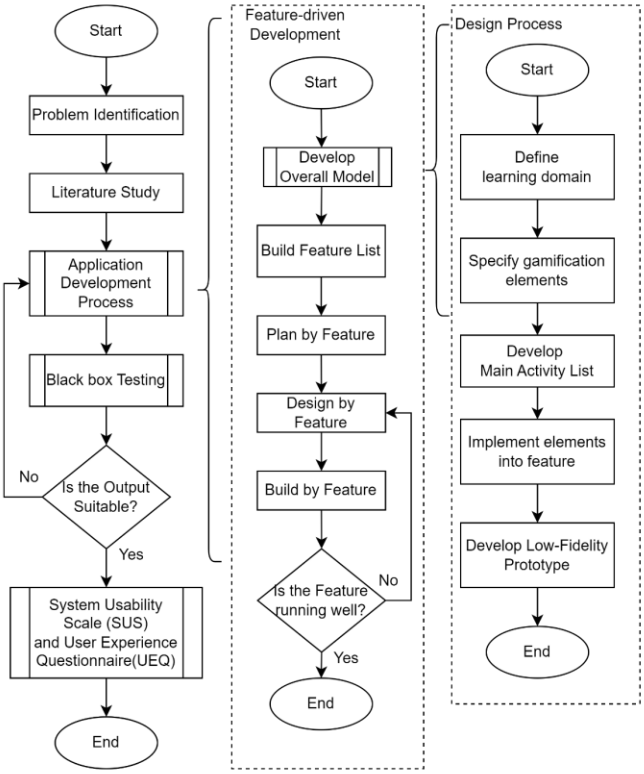

Figure 1. Research flow.

A. MECHANICS, DYNAMICS, AESTHETICS (MDA)

In gamification, the MDA approach is formally utilized by analyzing game design into three elements. The mechanics element outlines specific game rules and components in terms of actions, functioning as the process that drives user behavior. Dynamics describes how these rules are implemented during gameplay, translating player actions directly into the system and facilitating interactions between players. Meanwhile, aesthetics refers to the expected emotional responses from users when interacting with a gamified system [23].

The developed learning media focused on the declarative knowledge domain in CDSS, covering basic concepts such as definitions, components, design principles, and evaluation methods, all presented clearly for lay users. The materials included CDSS, medical diagnostic tests, and electronic health records (EHR). CDSS is explained as a key computational tool for assisting medical decisions. The CDSS content was followed by information on the implementation of DSS in a medical context, types of CDSS, the importance of medical diagnostic tests, and the role of EHR as a data source supporting medical decisions.

B. ACTIVITY-CENTERED DESIGN (ACD)

The initial step in system development involved identifying potential users. The findings were then utilized to develop a design using the ACD approach. This method ensures that the application is tailored to the user's activities. The selected activities were typical tasks commonly performed by individuals using electronic learning media. Subsequently, the primary activity served as the reference for feature development.

This list provides a detailed progression of the main activities outlined in Table I. These activities are organized into feature groups, each with specific components. Table I highlights the primary activities relevant to the developed

TABLE I
MAIN ACTIVITIES

ID	Main Activities
A-01	Google sign-in
A-02	View the main page dashboard
A-03	Learn a material
A-04	Take a short quiz on the material
A-05	View the Leader board order of related quizzes
A-06	View awards or achievements based on related quizzes
A-07	Log-out

application. The overall purpose of this learning application is for the CDSS. These main activities were formulated based on the created user personas, including learning the material and taking quizzes to assess comprehension. From this list, a use case diagram was created to represent the design of the application, as shown in Figure 2.

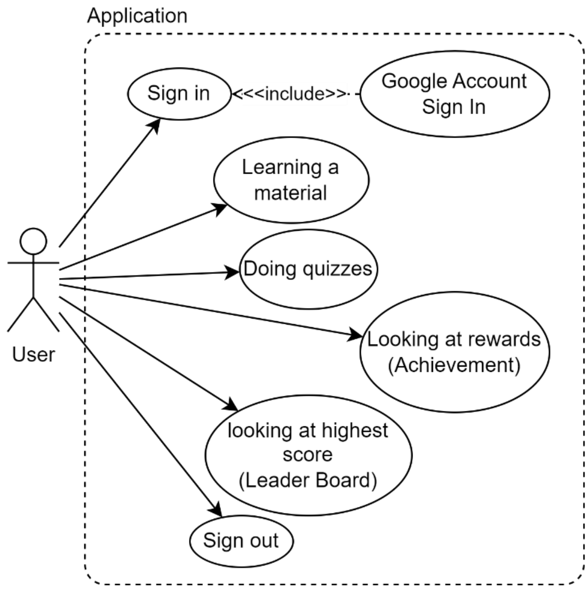

Figure 2. Use case diagram.

C. GAMIFICATION DESIGN

The gamification development process for this application depends on the learning domain or type of knowledge being implemented. In this case, the implemented science is CDSS, and the learning domain is declarative knowledge. Each learning domain incorporates unique gamification elements [24]. For declarative knowledge, these elements include story/narrative, sorting, matching, and replayability.

In the context of CDSS, this category encompasses the fundamental concepts of CDSS, including its definition, components, design principles, and evaluation methods. This type of knowledge, which consists of clear facts, information, and concepts, is suitable for lay users seeking to understand CDSS. Declarative knowledge in CDSS includes medical knowledge and related information that supports clinical decision-making.

The gamification element to be used was a story/narrative packaged as sequential material about CDSS. Additionally, this element could be incorporated into a short quiz to test understanding. The quiz could be taken repeatedly, aligning with the gamification element of replayability. These two elements were the main focus for further development in the gamification framework. The gamification development process utilized the MDA game design framework, consisting of mechanics, dynamics, and aesthetics. This approach integrates game elements into learning applications, tailored to the needs and objectives of the developed application. This design development followed the activities outlined in Table I, starting with the development of game mechanics.

D. BUILD FEATURE LIST

The ‘build feature list’ process included a list of features derived from the previously designed gamification framework. This list provides a more detailed development of the main activities outlined in Table I. Consequently, the primary activity features were organized into groups of feature sets, each containing additional feature components.

E. TESTING

At this stage, the developed applications were tested for usability by real users. Functionality testing was performed using a black-box approach. Additionally, usability testing was conducted using the SUS, and user experience was evaluated with the UEQ. SUS was used to assess the application’s usability, while UEQ measured its attractiveness and effectiveness in achieving gamification objectives. This testing involved students primarily from the Biomedical Engineering program who wanted to learn the basics of CDSS. Respondents read the instructions, tested the application by completing objectives within 10 minutes, and then filled out both the SUS and UEQ forms to evaluate usability and user experience, respectively.

1) BLACK BOX TESTING

Black box testing is a type of software testing that focuses on the functionality of an application. This method evaluates the inputs provided to a system and the expected outputs for each input. Black box testing is based on software requirements and specifications and is conducted without knowledge of the internal workings of the item under test. Also known as specification-based or behavioral testing, this technique does not require knowledge of the internal code implementation of the application [25]. Various test cases were designed and applied to the application to ensure the system functioned correctly.

2) SYSTEM USABILITY TESTING (SUS)

The SUS is a questionnaire designed to measure the usability of a system from the user’s subjective perspective. SUS test results are presented as scores ranging from 1 to 100, without involving complex calculations. The SUS questionnaire consists of ten questions with both positive and negative statements [26]. Respondents were asked to rate each statement on a scale of 1 to 5, where 1 means “Strongly Disagree,” 2 means “Disagree,” 3 means “Neutral,” 4 means “Agree,” and 5 means “Strongly Agree.”

For positive questions with odd numbers (1, 3, 5, 7, and 9), the contribution score was obtained by subtracting 1 from the scale position. For negative questions with even numbers, the contribution score was obtained by subtracting the scale position from 5. The total contribution value of each question was then multiplied by 2.5 to get the final SUS score. The final SUS score was calculated as the average SUS score of each respondent.

SUS scores were classified into several categories. SUS scores were classified into several categories. An average SUS score below 20.3 was in the “Worst” category. Scores ranging from 20.3 to 35.7, 35.8 to 50.9, 51 to 71.4, 71.5 to 85.5, 85.6 to 90.9, and above 90.9 were categorized as “Awful,” “Poor,” “OK,” “Good,” “Excellent,” and “Best,” respectively.

3) USER EXPERIENCE QUESTIONNAIRE (UEQ)

The UEQ is a questionnaire designed to measure the user experience of interactive products. It is frequently employed to evaluate the quality and usability of software based on user opinions [27]. The UEQ is an easy-to-use, reliable, and valid method for assessing user experience. This questionnaire can complement other evaluation methods to gather subjective quality assessments.

The UEQ questionnaire-based measurement evaluation was divided into six aspect scales, each containing 26 statement items. The UEQ aspects were explained as follows.

- Attractiveness: reflected the overall appeal of a product.
- Perspicuity: indicated how easy it was for users to understand and use the product.
- Efficiency: measured the speed at which users could complete tasks using the product without difficulty.
- Dependability: assessed the degree of control users had when using the product.
- Stimulation: evaluated the product’s ability to engage and motivate users.
- Novelty: gauged the level of innovation and creativity of the product.

The attractiveness scale consisted of six statements, while the other aspects scale consisted of four statements. Each statement had a seven-point scale, ranging from -3 to +3. The -3 range indicated the most negative response, 0 indicated a neutral response, and +3 indicated the most positive response. After collecting the UEQ questionnaire results, the next step was to analyze the questionnaire data.

The UEQ of a product was categorized into five categories based on the scale of the measured aspects. The “Excellent” category occurred when it was in the best 10% of results; “Good” when 10% of the results in the benchmark data set were better and 75% of other results were worse; “Above Average” when 25% of the results in the benchmark data set were better and 50% of other results were worse; “Below Average” when 50% of the results in the benchmark data set were better and 25% of other results were worse; and “Bad” when it was in the worst 25% of results.

IV. RESULTS AND DISCUSSION

This section starts by discussing the results of the MDA framework development. It then examines the features developed, followed by an explanation of the gamification design process, application development, and testing of each aspect. Finally, it describes the comprehensive testing of the application with real users or respondents.

A. MDA FRAMEWORK

The gamification development process utilized the MDA game design framework. This framework outlines a one-way relationship from designer to user, enabling designers to create functions (mechanics) that lead to various user interactions (dynamics), ultimately evoking emotions and experiences in the user (aesthetics). Designers typically approach game design by focusing on mechanics first, followed by dynamics, and then aesthetics, whereas players often experience the game starting with aesthetics, then dynamics, and finally mechanics. The use of these methods and designs was tailored to the needs and objectives of the gamification in the developed application.

1) MECHANICS

Game mechanics focus on the rules within the game. The game mechanics included in this application are as follows.

- The application has two modes: “Material Learning” and “Quiz.” The Learning mode covers basic material on CDSS, allowing users to read about topics ranging from general concepts to EHRs. The Quiz mode includes questions and answers to test users’ knowledge, and they can earn points for correct answers.
- Points incentivize users to complete tasks and achieve specific goals.
- “Achievements” reward users with certificates or badges when they reach specific goals or milestones.
- The “Time attack” feature adds a time challenge to the quiz, where the time taken also impacts the score.

2) DYNAMICS

After completing the game mechanics design, the game dynamics design was undertaken. Dynamics refers to the behavior of the game system resulting from the interaction between the player and the game mechanics. This includes responses to player actions, game flow, interaction patterns, and changes that occur as the game progresses. The game dynamics developed in this application are as follows.

- Sequentially accessed materials and quizzes are dynamic elements that engage users in exploring and acquiring knowledge in a structured manner. Users can navigate through the materials arranged in a specific order to systematically understand the application’s content.
- The leaderboard is a dynamic feature that lets users see their ranking as well as the rankings of other users in the app. This feature fosters a competitive environment, motivating users to achieve high scores and aim for the top of the rankings.

3) AESTHETICS

Aesthetics encompass the player’s feelings and emotions while playing, such as excitement, satisfaction, and challenge. The game aesthetics incorporated in this application are as follows.

- The unlocking part in sequences provides a sense of achievement when new material is unlocked.
- The onboarding guides new users through the dynamics of the game.
- Visual design creates an attractive interface that enhances the user experience and the appeal of the app.

B. DESIGN DEVELOPMENT

The implemented gamification elements were designed for the declarative knowledge learning domain. The core component of this design was a structured learning sequence, featuring arranged material and a quiz that could be repeated multiple times. The development of this gamification employed the MDA framework, which integrated game mechanics, dynamics, and aesthetics into the learning application.

Green was the primary color used in the app’s design, chosen for its fresh and healthy connotations. Selecting the appropriate color for the learning context enhanced the aesthetic appeal of the game, making it more attractive to users.

Figure 3. Logo of the MedQ application.

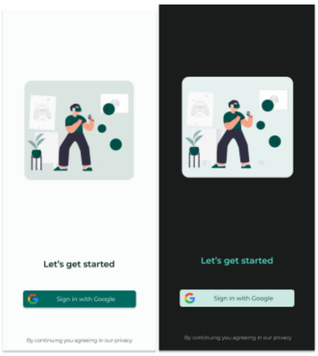

Figure 4. Hi-Fi on the sign-in feature set.

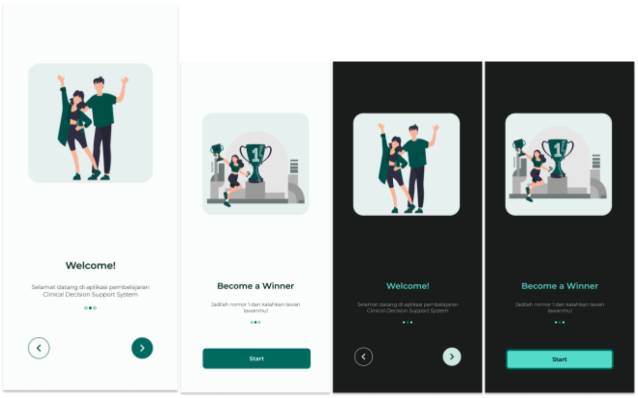

Figure 5. Hi-Fi feature set on boarding.

The app was named MedQ for simplicity and memorability, with MedQ standing for Medical Education Quiz.

The first result of this research was a high-fidelity wireframe design prototype of the developed application. This prototype was based on the created feature set and included both light and dark themes. Within each feature set, specific gamification elements that could be implemented were identified. Each feature set incorporated its gamification elements and objectives. From the developed prototype, a Flutter application was then created as the front-end, with Firebase serving as the back-end service. The application logo is shown in Figure 3.

The first feature is the sign-in page, which allows users to register and access the app using Google account authentication. The prototype of this sign-in page, shown in Figure 4, features a single button that requests Google authentication from the user. Images were added to enhance the app's aesthetics, and a dark theme was implemented to provide an appealing look when dark mode is used on mobile phones.

The next feature set includes an onboarding page, as shown in Figure 5. This page appears when the user has not signed in and aims to provide a dynamic overview of the user journey. The onboarding page consists of three screens, each displaying a different message. Navigation buttons allow users to switch between pages and proceed to the dashboard.

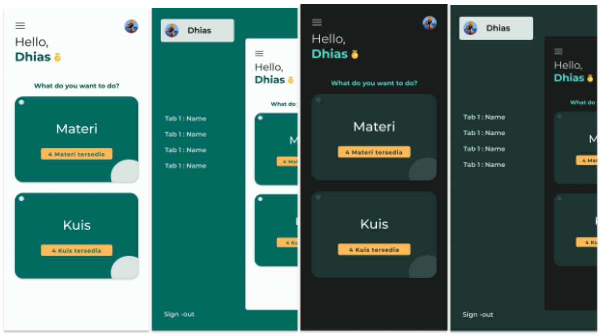

Figure 6. Hi-Fi feature set on the main page.

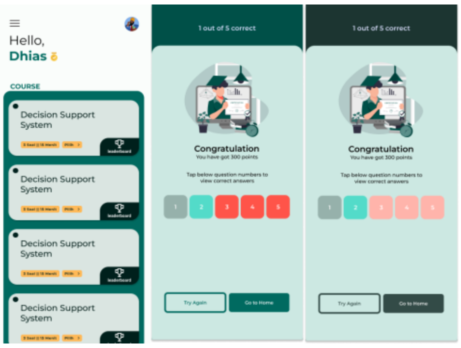

Figure 7. Hi-Fi interface of the quiz page.

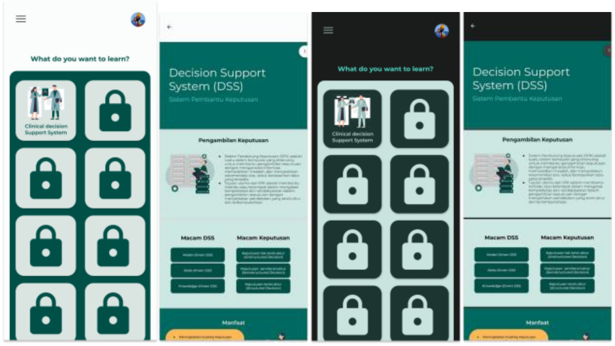

Figure 8. Hi-Fi of the material feature set.

Additionally, the main page of the application is part of this feature set, with the design depicted in Figure 6. This image is divided into visualizations of the main page and the drawer. The game modes, namely material mode for accessing provided materials and quiz mode for testing comprehension, are readily accessible. Both modes offer a game-like dynamic, allowing users to engage with materials and take quizzes. The page also includes side drawers for profile management and sign-out, as well as additional tabs for developer information and social media links pertinent to this study. The mechanics are illustrated through the placement of mode elements, while aesthetics is reflected in the user interface design. This includes the selection of a dark theme for a modern, contemporary look and the inclusion of the owner's profile photo.

The next feature set is the quiz-taking activity. First, a design was created to select a quiz, as shown in the list of available quizzes in the app. Each selection opens the quiz page, illustrated in Figure 7. The features related to quiz taking and navigation demonstrate the implementation of the mechanical factor. Each quiz list also includes a button to access the leaderboard feature. The sequential presentation of quizzes aims to convey a sense of game dynamics in this application.

The quiz page was divided into three sections: the quiz answering page, the quiz overview page, and the quiz answer

Figure 9. Hi-Fi of the leader board feature set.

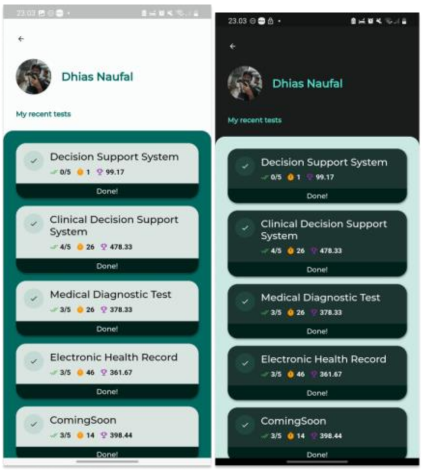

Figure 10. Hi-Fi of the profile set feature.

TABLE II
BLACK-BOX TESTING

ID	Main Activities	Results
A-01	The application can provide access and record users on the system.	Succeeded
A-02	The application can perform the functionality on the main page.	Succeeded
A-03	The application can perform the functionality on material features.	Succeeded
A-04	The application can perform functionality on the quiz feature.	Succeeded
A-05	The application can perform the functionality on the leader board feature.	Succeeded
A-06	The application can perform the functionality on the achievement feature.	Succeeded
A-07	The application can perform the functionality on the main page.	Succeeded

submission page. The game mechanics on this page involved time as a key factor in determining the quiz's duration. This time element also influenced the game dynamics by affecting the user's responses. Additionally, it regulated the point system, where users earned points based on their performance. The results page displayed the points earned and the number of correct answers. More correct answers and shorter completion times resulted in higher points. The aesthetics of this feature are consistent with the overall theme of the app. This feature set concluded with the results, which were calculated and stored in the app's database. Points were then sorted based on the highest scores. The results page is illustrated in Figure 8.

TABLE III
AVERAGE RESULTS OF UEQ TESTING

UEQ Scale (Mean and Variance)		
Attractiveness	1.933	0.71
Perspicuity	1.929	1.11
Efficiency	1.950	0.66
Dependability	1.750	0.95
Stimulation	1.721	0.75
Novelty	1.300	1.48

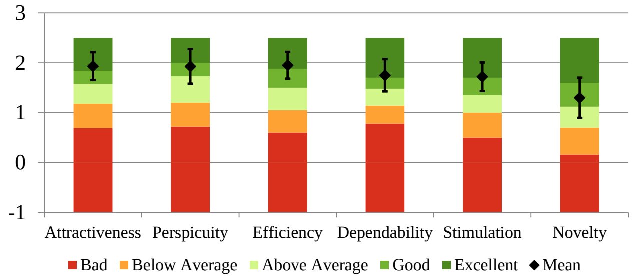

Figure 11. Graph of the average UEQ test results.

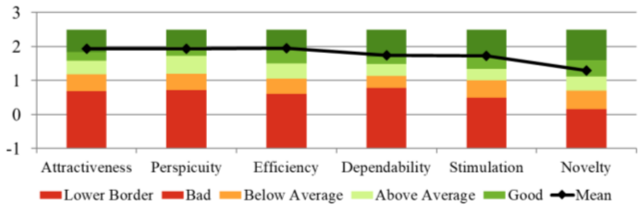

Figure 12. Graph of the UEQ test benchmark.

Figure 8 illustrates the design of the material set feature, which presents materials in PDF format accessible sequentially. This is part of the game dynamics implemented in the app. The feature aims to increase cognitive engagement by ensuring the user is actively involved in processing, analyzing, and interpreting information in sequence.

Figure 9 shows the design of the leaderboard page in both light and dark modes. The leaderboard sorted the points from completed quizzes within the quiz set feature. This is intended to enhance social student engagement in the MedQ application.

The point data collected by the user was extracted and sorted by the highest value. This feature is one of the dynamic elements of the application.

Completed quizzes were recorded on the profile page, similar to achievements earned after completion. Figure 10 shows the profile page design in both light and dark modes. This feature is part of the game mechanics. Users were rewarded based on their scores, which contributed to the game's dynamics, encouraging users to compete for more awards.

C. ANALYSIS OF TEST RESULTS

1) BLACK-BOX TESTING

The application capability was tested using black-box methods. Seven scenarios were evaluated, and all were successful. The results are shown in Table II.

2) SUS TESTING

Usability testing was conducted using the SUS questionnaire via Google Forms. Before the testing, respondents were informed about the application and asked to read and agree to a consent form. Upon approval, the testing commenced. Respondents explored all features of the MedQ application, including the quiz and material features, with complete freedom. After trying all the features, they filled out the SUS questionnaire on Google Forms. This test involved 38 respondents.

The MedQ test results showed an average SUS score of 74.9, indicating that the MedQ application falls into the "Good" category based on average score classifications. This average SUS score suggests that the MedQ application is both feasible and acceptable in terms of usability.

3) UEQ TESTING

Users experience testing was conducted directly using the UEQ questionnaire via Google Forms. This process was carried out concurrently with SUS testing. The average results of the UEQ scale for each aspect of user experience, compared to the UEQ benchmark for the MedQ application, are shown in Table III and Figure 11.

The MedQ app received average scores of 1.93 for both the attractiveness and perspicuity scales and 1.95 for the efficiency scale. On the dependability scale, the app achieved an average score of 1.75, while it scored 1.72 on the stimulation scale and 1.3 on the novelty scale. The UEQ test results are displayed in the benchmark graph in Figure 12.

The comparison results in Figure 12 indicate that the attractiveness, efficiency, dependability, and stimulation scores are at the "Excellent" level, ranking within the top 10% of results. In contrast, perspicuity and novelty scores fall into the "Good" category, with 10% of the benchmark results performing better and 75% performing worse. Overall, the MedQ app is rated "Excellent" for attractiveness, efficiency, dependability, and stimulation, but "Good" for perspicuity and novelty.

V. CONCLUSION

The MedQ application is an electronic learning medium specifically focused on CDSS. MedQ has been successfully developed through the implementation of five main activities. These activities include viewing the main page dashboard, learning the material, taking short quizzes on the material, viewing the leaderboard of related quizzes, and viewing awards or achievements based on the related quizzes. During development, MedQ was tested using three instruments. Functionality testing was conducted using black-box testing, resulting in a 100% success rate, indicating that all features run according to the predetermined criteria. Usability testing using the SUS scored 74.9, placing it in the "Good" category. User experience testing using the UEQ showed that the MedQ application falls into the "Excellent" category for aspects of attractiveness, efficiency, dependability, and stimulation, and into the "Good" category for aspects of perspicuity and novelty. This MedQ application is an initial prototype designed to introduce the basic concepts of CDSS. The content will be further developed by adding CDSS case examples to enhance students' understanding. MedQ will also be tested directly with a wider community of students and in classroom settings to support the learning process.

CONFLICTS OF INTEREST

The authors affirm that no conflicts of interest were present during the composition of this study.

AUTHORS' CONTRIBUTIONS

Conceptualization and methodology: Dhias Muhammad Naufal, Adhistya Erna Permanasari, and Paulus Insap Santosa; Software: Dhias Muhammad Naufal; Validation: Adhistya Erna Permanasari and Paulus Insap Santosa; Writing – original draft: Dhias Muhammad Naufal, Adhistya Erna Permanasari; Writing – reviewing and editing: Adhistya Erna Permanasari; Visualization: Adhistya Erna Permanasari; Project administration: Adhistya Erna Permanasari, Silmi Fauziati, and Indriana Hidayah; Funding acquisition: Adhistya Erna Permanasari, Silmi Fauziati, and Indriana Hidayah.

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REFERENCES

[1] R. Takahashi and Y. Kajikawa, "Computer-aided diagnosis: A survey with bibliometric analysis," *Int. J. Med. Inform.*, vol. 101, pp. 58–67, May 2017, doi: 10.1016/j.ijmedinf.2017.02.004.

[2] A. Teufel and H. Binder, "Clinical decision support systems," *Visc. Med.*, vol. 37, no. 6, pp. 491–497, Dec. 2021, doi: 10.1159/000519420.

[3] A.J. Irawan, F.A.T. Tobing, and E.E. Surbakti, "Implementation of gamification Octalysis method at design and build a react native framework learning application," in *2021 6th Int. Conf. New Media Stud. (CONMEDIA)*, 2021, pp. 118–123, doi: 10.1109/CONMEDIA53104.2021.9617171.

[4] J. Schell, *The Art of Game Design: A Book of Lenses*, 3rd ed. Boca Raton, FL, USA: CRC Press, 2019.

[5] E. Pradanika, Y. Widyani, and Y. Rusmawati, "Designing gamification for programming learning applications," in *2022 Int. Conf. Data Softw. Eng. (ICoDSE)*, 2022, pp. 18–23, doi: 10.1109/ICoDSE56892.2022.9972176.

[6] F. Marisa *et al.*, "Gamifikasi (gamification) konsep dan penerapan," *JOINTECS (J. Inf. Technol. Comput. Sci.)*, vol. 5, no. 3, pp. 219–228, Sep. 2020, doi: 10.31328/jointecs.v5i3.1490.

[7] A.N. Saleem, N.M. Noori, and F. Ozdamli, "Gamification applications in e-learning: A literature review," *Technol. Knowl. Learn.*, vol. 27, no. 1, pp. 139–159, Mar. 2022, doi: 10.1007/s10758-020-09487-x.

[8] M. Sailer and L. Homner, "The gamification of learning: A meta-analysis," *Educ. Psychol. Rev.*, vol. 32, pp. 77–112, Mar. 2020, doi: 10.1007/s10648-019-09498-w.

[9] L.F. Rodrigues, A. Oliveira, and H. Rodrigues, "Main gamification concepts: A systematic mapping study," *Heliyon*, vol. 5, no. 7, pp. 1–13, Jul. 2019, doi: 10.1016/j.heliyon.2019.e01993.

[10] J. Koivisto and J. Hamari, "The rise of motivational information systems: A review of gamification research," *Int. J. Inf. Manag.*, vol. 45, pp. 191–210, Apr. 2019, doi: 10.1016/j.ijinfomgt.2018.10.013.

[11] J. Hu, "Book reviews: Gamification in learning and education: Enjoy learning like gaming," *Br. J. Educ. Stud.*, vol. 68, no. 2, pp. 265–267, Apr. 2020, doi: 10.1080/00071005.2019.1682276.

[12] J.M.P. Andreu, "Una revisión sistemática sobre gamificación, motivación y aprendizaje en universitarios," *Teoría de la Educación. Revista Interuniversitaria*, vol. 32, no. 1. pp. 73–99, Jan.-Jun. 2020, doi: 10.14201/teri.20625.

[13] K. Krishnamurthy *et al.*, "Benefits of gamification in medical education," *Clin. Anat.*, vol. 35, no. 6, pp. 795–807, Sep. 2022, doi: 10.1002/ca.23916.

[14] E. Pesare, T. Roselli, N. Corriero, and V. Rossano, "Game-based learning and gamification to promote engagement and motivation in medical learning contexts," *Smart Learn. Environ.*, vol. 3, pp. 1–21, Apr. 2016, doi: 10.1186/s40561-016-0028-0.

[15] S. Felszeghy *et al.*, "Using online game-based platforms to improve student performance and engagement in histology teaching," *BMC Med. Educ.*, vol. 19, pp. 1–11, Jul. 2019, doi: 10.1186/s12909-019-1701-0.

[16] I. Cretu, M. Grigore, and I.S. Scripcariu, "Get ready for gen Z, our next generation of medical students," *Rev. Cercet. Interv. Soc.*, vol. 69, pp. 283–292, Jun. 2020, doi: 10.33788/rcis.69.18.

[17] Leilimosalanejad and S. Abdollahifard, "Gamification in psychiatry: Design and development of native model and the innovate strategy in medical education as a funny and exciting learning," *Pak. J. Med. Health Sci.*, vol. 12, no. 4, pp. 1820–1828, Oct.-Dec. 2018.

[18] F.A. dos Reis Lívero *et al.,* “Playfulness in the classroom: Gamification favor the learning of pharmacology,” *Educ. Inf. Technol.*, vol. 26, no. 2, pp. 2125–2141, Mar. 2021, doi: 10.1007/s10639-020-10350-w.

[19] Z. Athiyah, A.E. Permanasari, and S. Wibirama, “Development of gamification design on heart anatomy learning media,” in *2022 4th Int. Conf. Biomed. Eng. (IBIOMED)*, 2022, pp. 97–102, doi: 10.1109/IBIOMED56408.2022.9987817.

[20] M.D. Szeto *et al.,* “Gamification and game-based strategies for dermatology education: Narrative review,” *JMIR Dermatol.*, vol. 4, no. 2, Jul.-Dec. 2021, Art. no. 30325, doi: 10.2196/30325.

[21] L.F. Hamdi, B.S. Hantono, and A.E. Permanasari, “Gamification methods of game-based learning applications in medical competence: A systematic literature review,” in *2022 Int. Symp. Inf. Technol. Digit. Innov. (ISITDI)*, 2022, pp. 50–54, doi: 10.1109/ISITDI55734.2022.9944535.

[22] G. Gay and H. Hembrooke, *Activity-Centered Design: An Ecological Approach to Designing Smart Tools and Usable Systems*. Cambridge, MA, USA: MIT Press, 2004.

[23] R. Hunicke, M. Leblanc, and R. Zubek, “MDA: A formal approach to game design and game research,” in *Proc. AAAI Workshop Chall. Game AI*, 2004, pp. 1–5.

[24] K.M. Kapp, *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education.* San Francisco, CA, USA: Pfeiffer, 2012.

[25] B. Beizer and J. Wiley, “Black box testing: Techniques for functional testing of software and systems,” *IEEE Softw.*, vol. 13, no. 5, pp. 98, Sep. 1996, doi: 10.1109/ms.1996.536464.

[26] C. Hass, “A practical guide to usability testing,” in *Consumer Informatics and Digital Health: Solutions for Health and Health Care*. Cham, Switzerland: Springer, 2019, ch. 2, sec. 6, pp. 107–124.

[27] M. Schrepp. *User Experience Questionnaire Handbook Version 8*. (2019). Access date: 19-Aug-2023. [Online]. Available: www.ueq-online.org