

Application of Gamification in Digital Library Systems Based on MDA Framework

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(Received: 7 Oct 2025, revised: 1 Dec 2025, 23 Dec 2025, accepted: 8 Jan 2026)

Abstract

The digital library of Bhinneka Nusantara University has experienced low user engagement, with an average of only 166 visits per month as of June 2025. This study aims to design and evaluate a gamified digital library system to address this issue. The system integrates key gamification elements points, leaderboards, and challenges and badges based on the Mechanics and Aesthetics components of the Mechanics–Dynamics–Aesthetics (MDA) Framework. The system was developed using the System Development Life Cycle (SDLC), encompassing needs analysis, system design, gamification implementation, and testing. Functional testing and User Experience (UX) evaluation were conducted to assess the effectiveness of the system. The results show that the gamified features have a positive impact on user perception, satisfaction, motivation, and pleasure.

Keywords: Digital Library, Gamification, MDA Framework, User Experience

I. INTRODUCTION

According to data from the University of Bhinneka Nusantara digital library, digital library usage is still low, with an average of 166 visits per month until June 2025. Low user engagement is the main problem faced by the University of Bhinneka Nusantara digital library.

Gamification is defined as the application of game elements and mechanics into non-game activities to increase people's engagement and motivation for better outcome [1]. There are seven gamification elements: onboarding, leaderboards, badges, points, challenges & quests, levels, and social engagement loops. These game elements generally have a positive impact in various contexts, such as healthcare services, marketing, and education [2]. Moreover, these elements can be adapted to user characteristics such as age, gender, culture, and preferences [3]. Therefore, gamification element is able to motivate and encourage them to achieve certain goals [4].

Previous research has shown that gamification can increase user engagement. It was found that the implementation of gamification elements such as points, challenges, and leaderboards increased student engagement by up to 40% in MAN 2 Mojokerto library [5]. However, their study did not apply evaluate user emotional responses.

The Mechanics-Dynamics-Aesthetics (MDA) framework, originally developed for game design, has been adapted for a variety of applications, including library website redesign and

gamification in education [6]. In library website design, MDA emphasizes security, accessibility, and user appeal [7]. However, in this study, it emphasizes functionality for mechanics component and perception, satisfaction, motivation, and pleasure for aesthetics component. While most prior research implemented gamification elements independently, few applied a theoretical framework such as the MDA (Mechanics, Dynamics, Aesthetics) model.

Recent studies applying the MDA (Mechanics–Dynamics–Aesthetics) framework have primarily focused on gamifying e-learning platforms and LMS environments, reporting consistent improvements in engagement and affective outcomes but differing in scope and measurement approaches. For example, Pardede et al. applied MDA to e-learning design and argued that carefully designed mechanics are essential to produce positive dynamics and desirable aesthetics in online courses [8]. Other work formalized MDA models for higher-education systems (using state-machine modeling) and demonstrated how explicit mechanic dynamic mappings can support predictable aesthetic outcomes such as motivation and satisfaction [9]. A recent personalized gamification study also confirmed gains in flow, motivation, and enjoyment when mechanics were tailored to learners, suggesting that aesthetics outcomes are sensitive to how mechanics are instantiated [10]. In contrast to these prior works, the present study applies the MDA framework specifically to a university digital-library context and evaluates emotional impact quantitatively across perception,

satisfaction, motivation, and pleasure using a standardized UX survey thus filling a gap where previous MDA applications emphasized engagement broadly but lacked fine-grained, instrumented measurement of emotional outcomes.

Therefore, this study aims to analyze and design the digital library system of Bhinneka Nusantara University by integrating gamification based on the Mechanics and Aesthetics components of the MDA Framework. The novelty of this study lies in applying the MDA framework (specifically mechanics and aesthetics) within a digital library system and quantitatively evaluating its emotional impact through UX testing. Another study mentioned that gamification has the potential to improve service quality and user participation levels in digital library systems [11]. This study places a stronger emphasis on the design and direct implementation of gamification features (point system, leaderboard, badges, levels, and rewards) within the digital library system. Consequently, the research is positioned within the scope of mechanical design (mechanics) and the evaluation of users' emotional responses (aesthetics). The dynamics component is inherently related to emergent behavior—behavior that naturally arises after the features are used by a large number of users over a certain period of time. Since this study does not focus on a longitudinal approach or behavioral analysis based on long-term user interactions, the dynamics component is therefore not considered as a primary focus.

II. RESEARCH METHODOLOGY

This research is an information system development research using descriptive and quantitative methods for evaluation. SDLC is used as a system development approach. MDA Framework is used for designing gamification features, focusing on mechanics and aesthetics aspects. Recent work on software and information system development demonstrates that SDLC remains a widely adopted methodology because it provides a well defined, stepwise process for planning, designing, building, testing, and deploying applications [12], [13]. This clear structure makes SDLC particularly suitable for integrating gamification design under the MDA framework. The mechanics of gamification such as point systems, leaderboards, and rewards can be systematically implemented during the design and coding phases, while later during the testing phase the system's usability and emotional impact (that correspond to the aesthetic component) can be rigorously evaluated. By using SDLC, developers ensure that gamification elements are properly implemented before assessment of user experience, thus preserving internal validity and allowing a reliable measurement of whether the mechanics produce the intended emotional and motivational effects. The stages of SDLC that are integrated with MDA are as follows.

A. Requirement Analysis

This stage is an important process in obtaining the needs of the system to be designed and developed. At this stage we

analyze the problem of why users rarely access digital libraries to determine mechanics. Data collection in the initial analysis was carried out by conducting interviews with students and librarians.

B. System Design

At this stage, the researcher designs the main gamification features that will be included in the system. At this stage, the researcher also determines the rules of the game that will have an impact on aesthetics. This aesthetic impact is how users feel about the gamification system of digital library. This is important to ensure that the mechanics design will produce a positive experience (aesthetics).

C. Gamification Element Implementation

At this stage, it is necessary to ensure that the gamification elements are not only designed to be attractive, but also can be accessed and understood easily by digital library users. The features in this study are limited to point system, badge and awards, challenges (challenges/quests), leaderboard, and user Level.

D. Testing

At this stage, functional mechanics testing is carried out. The goal is to ensure that the gamification features designed in the digital library run technically correctly, as expected. The method used is blackbox testing. Black-box testing ensures that the system fulfills the functional requirements, which is particularly crucial when the system is designed based on predefined specifications (such as the definitions of gamification mechanics). When a specific input is executed (e.g., login or claiming a reward), the expected output should occur (such as points increasing or badges appearing); if this happens, the test is considered successful. This process is essential to validate that the gamification mechanics have been correctly implemented [14].

Aesthetics Test using user experience (UX) testing [15], [16]. The goal is to assess how users feel the emotional experience when interacting with the gamification system. Indicator of aesthetics are perception, satisfaction [16], motivation, pleasure [17]. Respondents answered questions on a Likert scale of 1-5 and the results were analyzed using an average calculation. The UX evaluation employed a 5-point Likert scale (1 = "strongly disagree"; 2 = "disagree"; 3 = "undecided"; 4 = "agree"; 5 = "strongly agree"), which enables the interpretation of user responses along a continuum ranging from very negative (1) to very positive (5) perceptions toward the system. Thus, the higher the score obtained, the more positive the user experience, while lower scores reflect negative or unfavorable responses [18].

For aesthetic testing using UX testing using the questionnaire. The instrument validity was tested using Pearson's correlation with a significance level of 0.05 and N = 50. All questionnaire items achieved r-count values higher than the r-table value (0.279) with Sig. < 0.05, indicating that all items were valid. Furthermore, the reliability test using Cronbach's Alpha produced a total value of 0.892. Therefore, the questionnaire as shown in Table 1, is considered both valid

and reliable for measuring user perception, satisfaction, motivation, and pleasure.

Table 1. Questionnaire Statement for UX Testing

Aspect	Questionnaire Statement
Perception	The appearance of this digital library system is attractive and modern. The gamification features are easy to understand and use. This system is better than the previous digital library appearance.
Satisfaction	I am satisfied with the use of this system overall. I am satisfied with the point system, badges, and challenges. I am satisfied with the appearance of the leaderboard and user levels.
Motivation	This system makes me more motivated to use the library. I want to continue to level up or rank on the leaderboard. I am encouraged to log in every day to get points and rewards.
Pleasure	I feel happy when I complete challenges and get rewards. This system makes reading activities more interesting and enjoyable. I want to use this system again in the future.

Indicators of the perception are that system is easy to understand, the appearance of this system is attractive, the gamification features feel relevant and not annoying, and the system makes the reading experience different from before. The indicators of this satisfaction are the points and challenges features in the system are satisfying, this system helps me in using the digital library, user will recommend this system to others, and user feel satisfied after completing a mission or getting a badge. Indicators of motivation are that users are motivated to log in every day to get points, users are encouraged to complete challenges to move up in ranking, users want to collect as many badges as possible, and this system makes users want to return to access the digital library. Indicators of enjoyment are users enjoying the gamification features in this system, users feel happy when using this system, challenges and games make the reading experience more exciting, and this system makes reading activities less boring.

This study employed purposive sampling, where respondents were selected based on specific criteria: (1) active students of the University of Bhinneka Nusantara were familiar with e-learning platforms or web-based academic systems, and (2) had prior experience using the digital library. This approach ensures that the participants accurately represent the actual target users of the proposed gamified digital library system.

This research is limited to the system testing stage on the functionality and user experience (UX) aspects. The deployment stage to the campus digital library system and

system maintenance were not carried out due to time constraints, system access, and the focus of the research which was directed at the design and evaluation of gamification features.

III. RESULTS AND DISCUSSION

A. Requirement Analysis

Based on data collected from the digital library of University of Bhinneka Nusantara, visitor statistics over the past six months show fluctuations in engagement.

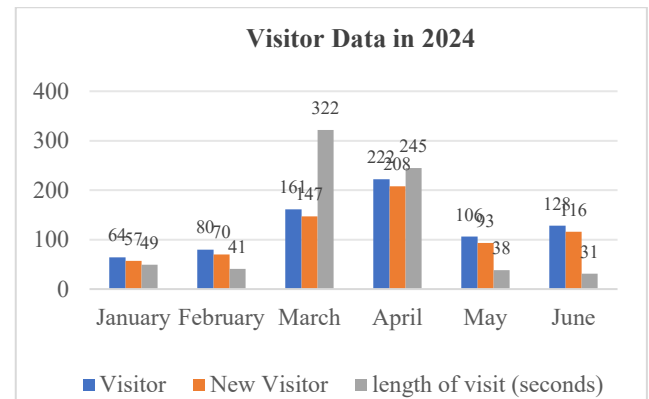


Figure 1. Visitor Statistics Over the Last Six Month

From Figure 1, we can observe a sharp increase in the number of visitors and new visitors between April and July. However, after that period, there was a decline in both the number of visitors and the duration of visits. The highest visit duration in March indicates that users were more engaged with the content during that month, but interest started to decline in May and June. The very short visit duration (only a few seconds) suggests that visitors were not interested in browsing the University of Bhinneka Nusantara's digital library website.

A short visit duration on a website often indicates that the content is not engaging. One contributing factor is the quality of the content not meeting user expectations. When the content does not provide value or is uninteresting, users tend to leave the page quickly, leading to an increased bounce rate and a decrease in session duration. This issue arises from an unsatisfactory user experience. From the results of interviews with 10 students and 2 librarians, the following there is no need to open the library website, users feel that reading in the digital library is passive and boring, there is no incentive after using the system, users do not feel competitive or motivated by other users, and users do not feel appreciated for certain achievements.

The Table 2 below helps in understanding the complexity of the problem, its impact, and potential solutions to resolve or at least mitigate its effects. User interface changes can help integrate gamification elements such as points, leaderboards, or challenges that can increase user engagement and motivation to return to the platform [19], [20]. So, the solution in Table 2 is to create a friendly user interface and use

gamification elements. Elements such as leaderboards, badges, and rewards have been proven to increase user engagement in digital libraries. Research results show that gamification can motivate users to be more active in using digital library services [21], [22]. The Challenge & Quest elements help users to stay motivated in using digital services, including libraries, by providing specific objectives to achieve. This not only increases engagement but also increases user interaction time with the system. Users are encouraged to come back and complete the challenges offered, thus increasing the frequency of visits.

To ensure that gamification does not solely stimulate entertainment-based interactions, academic motivations are explicitly integrated into the mechanics design. For example, reading books and completing topic-based quizzes, and exploring newly added resources are linked with reward systems, thereby aligning user engagement with the core mission of a digital library facilitating research and knowledge discovery

Table 2. Results of Needs Analysis and Design of Gamification Mechanics

Problem	Gamification Features (Mechanics)	Solution	Aesthetics
There is no need to open the library website	Point System	Claim daily login points twice.	Pleasure Perception
Users feel that reading in the digital library is passive and boring	Challenge	Complete reading one book to the last page and wait until the timer ends.	Motivation Perception
There is no incentive after using the system	Point System	Giving points for activities such as logging in, reading, completing quests as a form of direct appreciation.	Pleasure Perception
Users do not feel competitive or motivated by other users	Leaderboard	Displays user rankings based on total points, motivating participation through healthy competition.	Satisfaction Motivation Perception
Users do not feel appreciated for certain achievements	Badge and Awards	Symbolic rewards (e.g. Gold, Silver, Bronze) encourage a sense of pride and personal accomplishment	Satisfaction Pleasure Perception

The points system is also very effective in increasing user engagement by rewarding each interaction made, such as searching for or borrowing books. Studies in digital library environments have found that users are more likely to perform additional interactions if they earn points in recognition for their activities. These points can be converted into other incentives, such as rewards or rankings on leaderboards, further enhancing competition and motivation to use the platform [23].

The design of this gamification elements concept above will be the basis for analyzing system requirements. This

analysis aims to ensure that all needs are met during information system development process. The following are the results of the requirements analysis. The information system must be able to implement gamification elements in several existing features: the system must be able to reward players with points when they do daily login, when the player successfully completes the book, to provide various forms of missions and make them the main missions, to provide side missions in the form of quizzes and to display the order of leaderboard for each program.

B. System Design

The challenge & quest element are implemented to increase users' engagement and encourage them to achieve specific goals. These interactions are done in an enjoyable and educational manner. To earn points, users must complete the missions provided. The missions are divided into main missions and side missions. Below in Table 3 are some examples of main missions.

Table 3. Example of Challenges in The Main Mission

Mission Name	Description	Points
Login for 2 day	Claim daily login points twice.	30
Read a Book	Complete reading one book to the last page and wait until the timer ends.	150
Complete 8 Puzzles	Solve an 8-piece puzzle correctly without time or movement restrictions.	75
Special login	Log into the application on specific days (e.g., Independence Day). Can only be claimed on the event day.	25
Answer a Question	Correctly answer a question to earn points.	30

In the side missions, players complete interactive quizzes that are engaging and educational for player. They will get various of question topics. Each question has four answer options and each question has equal points. So, the players can estimate the points that will be obtained from the correct answers. In addition to earning points, this quiz is also able to increase the player's knowledge and insight.

The leaderboard element ranks players based on their accumulated points. This ranking serves as a strong motivation for players, fostering a competitive environment. As a result, this element promotes healthy competition among players and encourages them to be more active in using the system [24].

Player rankings are determined by the total points collected during a season. Each student competes only with others from the same academic program. A new season begins at the start of each term, and only the top three players receive bonus points as rewards. The point calculation is designed to balance opportunities between new and returning players in achieving the top rank. The following Table 4 shows the point distribution based on rankings:

Table 4. Leaderboard Reward

Rank	Point
Gold Medal (1 st Place)	300
Silver Medal (2 nd Place)	175
Bronze Medal (3 rd Place)	90

The points element (Table 5) is used as a reward for actions and achievements completed by players. By receiving rewards, players feel appreciated, which in turn triggers positive emotions. Additionally, players will recognize that the more points they accumulate, the greater the benefits they receive.

As a result, players will be continuously motivated to earn as many points as possible to maximize their advantages. This element has the most significant impact on enhancing player engagement and motivation [25].

Table 5. Point Conversion Into Special Abilities

Points	Reward
5,000+	Extend book borrowing duration by 3 days beyond the maximum limit.
7,500+	Gain access to exclusive books.
12,500	Convert points into special task credits.
20,000	Free binding service for final project submission.

The point system uses experience points (XP) that accumulate continuously. Players earn more XP for completing more difficult tasks. Points can be earned through daily login by claiming once per day, finishing a book by reaching the last page and waiting for the timer, completing main missions, finishing side missions (quizzes) and ranking in the leaderboard, where the top three players receive bonus XP each season. XP can be used to unlock various rewards at certain thresholds.

C. Gamification Element Implementation

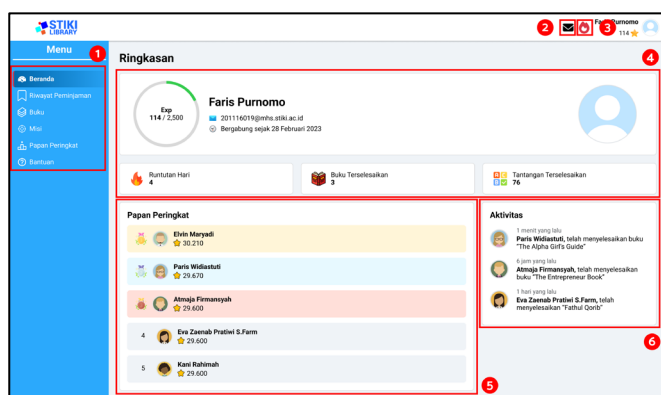


Figure 2. Home Page Interface Design

There are many components of that interface (Figure 2), for instance: (1) Sidebar navigation that allow the users to switch between different menus easily. (2) Inbox Button, it is for displaying messages or notifications from the system, (3)

Daily login reward, The user can check their login and claim daily points, (4) User Information, it is showing the details such as accumulated points, name, email, and login account. (5) Leaderboard preview, it is displaying the rank of seven players with the highest points, (6) Recent log activity, it is displaying the latest achievements and activities from the other users.

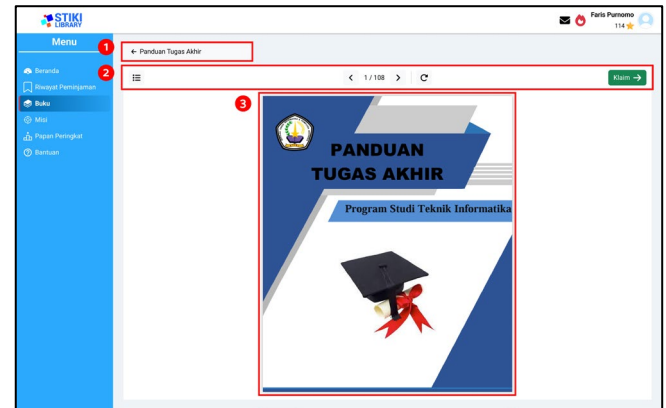


Figure 3. Book Reading Page Interface Design

There are two components of that interface (Figure 3) include: (1) Book Title & Back Button, it displays the title of the book and allows the user to return to the previous page, (2) Toolbar buttons include options such as: table of content, page navigation, rotation tool, claim button.

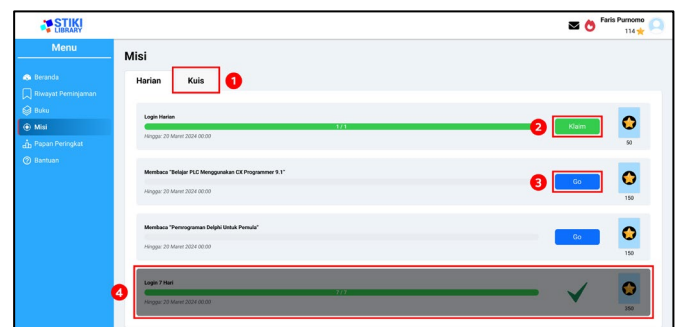


Figure 4. Missions Page Interface Design

The Missions Page (Figure 4) is designed to encourage user engagement by offering various tasks that reward points upon completion. The key components of this interface include: (1) Quiz Tab Button, displays a list of available quizzes that users can complete as side missions, (2) Claim Button, allows users to claim points after successfully completing a mission, (3) Mission Details Button, provides more information about a specific mission, including requirements and rewards, (4) Completed Mission Indicator, shows missions that have been finished and points that have been claimed.

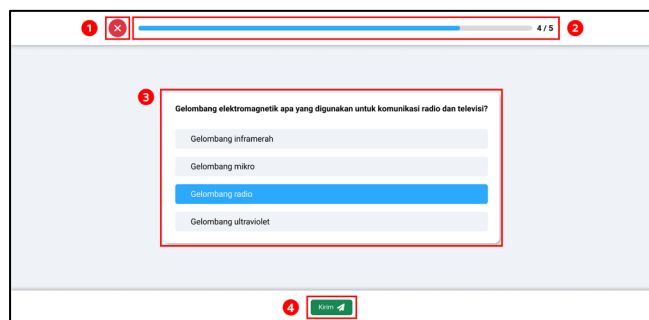


Figure 5. Quiz Detail Page Interface Design

The Quiz Detail Page (Figure 5) is designed to provide an interactive and structured quiz experience for users. The key components of this interface include: (1) Back Button, allows users to return to the previous page, (2) Quiz Progress Indicator, displays the user's progress in completing the quiz, (3) Question Section, shows the current question with four multiple-choice answers, (4) Submit Answer Button, enables users to submit their answer after making a selection.

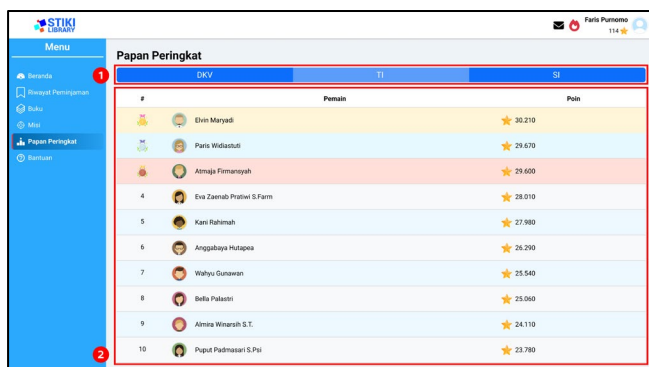


Figure 6. Leaderboard Page Interface Design

The Leaderboard Page (Figure 6) is designed to display the scoreboard based on accumulated points, fostering a sense

of competition and motivation. There are two components of this interface include: (1) Program Selection Button, which allows the user to view the leaderboard for different academic programs. (2) Ranked Player List, which displays the top players within the selected program, sorted by their total points.

Table 6 presents the results of Black Box testing conducted to evaluate the functional mechanics of the gamification features implemented in the digital library system. Each row represents a test case designed to verify whether the system behaves correctly in response to specific user actions. Daily login points is awarding users with points when they log in for the first time or on a special day. Point accumulation is granting points after completing reading tasks. Leaderboard update is updating user ranks based on their accumulated points. Challenges is verifying that points and completion notifications are given when users complete tasks or answer questions. Badge unlocking is ensuring badges are awarded for consistent login behavior (e.g., logging in for 7 consecutive days). All test scenarios returned the expected output and were marked as “Success”, indicating that each gamification mechanic functions correctly and supports user engagement goals.

In this research, black-box testing was not merely conducted as a descriptive functional validation but played a crucial role in verifying that the gamification mechanics were correctly implemented within the digital library system. Each mechanic (such as daily login rewards, point accumulation, leaderboard updates, badge unlocking, and level progression) was tested to confirm that the expected outputs were produced from specific user interactions. This procedure aligns with the principles of the MDA framework, where mechanics must be technically operational before aesthetics (user emotions and engagement) can be reliably evaluated [26]. The evidence suggests that functional correctness acts as a foundational requirement for meaningful UX evaluation in gamified contexts, ensuring that user reactions reflect the designed experience rather than system limitations [27].

Table 6. Result of Functional Mechanics Testing

No	Feature	Test Scenario	Input	Expected Output	Status
1	Daily Login Point	User login today for first time	User login at 8 am and 2 pm	System add +30 point	Success
2	Login in Special Day	User login in special Day	User login in May 1, 2025	System add +25 point	Success
3	Point Accumulation	Complete reading one book to the last page and wait until the timer ends.	Click “OK”	System add +75 poin	Success
4	Leader-board	Users add points and the system give the position on the leaderboard.	User has 130 point and goes up to 210	Username rise to higher ranks on the leaderboard.	Success
5	Challenge	User completes all challenge requirements (eg: completing a puzzle)	Click “OK”	System show notification “Challenge complete!” dan +75 poin	Success
6	Challenge	User answer question	Click “Complete”	System show notification “Challenge complete!” dan +30 poin	Success
7	Badge Unlock-ing	User successfully logged in for 7 consecutive days	Login on the 7 th day	System give badge “Gold Metal”	Success

For aesthetic testing using UX testing using the questionnaire in Table 1. Testing was conducted on 50 users. To conduct initial validation and exploratory UX studies, it is sufficient to use a minimum of 30 respondents [28]. The demographic analysis (Figure 7) shows that the majority of respondents were male (64%), while female respondents accounted for 36%. Three age ranges were represented, namely 18–20 years (30%), 21–23 years (50%), and above 23 years (20%), indicating that the digital library was tested by users with different levels of academic maturity. Regarding academic background, 40% were from Informatics, 30% from information system, and 30% from visual communication design, demonstrating that the system can accommodate diverse academic needs. Additionally, most respondents accessed the previous digital library less than once per week (60%), which supports the relevance of implementing gamification to increase engagement. This demographic profile provides a diverse sample for UX evaluation and reinforces the external validity of the findings.

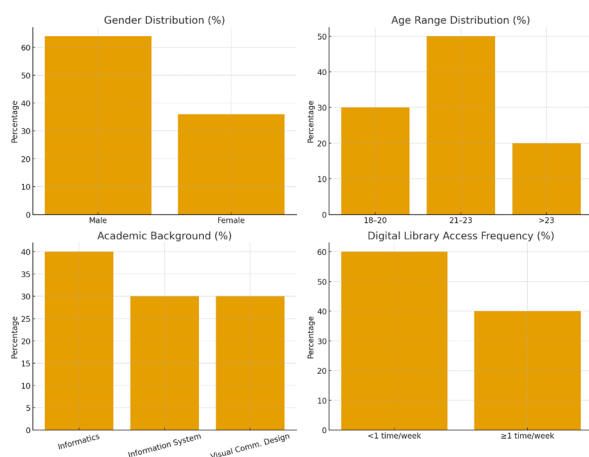


Figure 7. Respondent Demographics

The results of the test (Table 7) obtained an Average Perception of 4.13; Satisfaction 4.07; Motivation 4.33; and Pleasure 4.27. Mean scores matched the expected values, with low standard deviation (0.13–0.15) for all indicators, indicating consistent responses across participants. Furthermore, the 95% confidence interval (CI) for each UX indicator lies entirely above the neutral threshold (3.00), suggesting that the positive responses did not occur by chance but were statistically reliable. These findings reinforce the validity of the UX results and provide empirical evidence that the mechanics driven gamification features successfully generated positive aesthetic experiences in the digital library system.

Table 7 Result of Functional Mechanics Testing

UX Indicator	Ave-age Score	SD	95% CI Lower	95% CI Upper	Interpretation
Perception	4.13	0.140	4.057	4.135	Positive
Satisfaction	4.07	0.131	4.036	4.109	Positive
Motivation	4.33	0.152	4.282	4.366	Positive
Pleasure	4.27	0.134	4.245	4.320	Positive

The motivation and pleasure aspects are at the highest value, meaning that the system has succeeded in encouraging users to return to using the digital library in a fun way. Perception (4.13) shows that the majority of respondents consider the system's appearance and navigation attractive and easy to use. This indicates that the aesthetics aspect of the MDA framework has been met well. Satisfaction (4.07) shows that users are satisfied with gamification features such as the point system, challenges, and leaderboards. Although quite good, there is still room for development to improve convenience and feature variety. Motivation (4.33) is the highest value of all aspects. This indicates that the system has succeeded in increasing users intention and enthusiasm to use the digital library regularly. Mechanics and dynamics elements such as challenges, badges, and user levels have succeeded in triggering active involvement. Enjoyment (4.27) shows that users feel the experience of using the system is fun and not boring. This is important to increase user retention and loyalty in the long term. The results of this study are in line with previous research which shows that gamification elements in brand applications can increase user motivation, perception, satisfaction, and enjoyment [29].

All value indicates a positive user response to all aspects of the system's gamification. These scores indicate that the users experienced a positive emotional response while interacting with the system, which aligns with the Aesthetics component of the MDA framework. Since the gamification mechanics had been validated through black-box testing and functioned as expected, the positive UX outcomes suggest that the mechanics were able to successfully translate into meaningful user experiences. This finding supports previous literature that game mechanics can compensate for e-learning's traditional emotional limitations [30]. Moreover, the results provide theoretical evidence that the MDA framework is applicable not only in entertainment and education, but also in academic digital libraries, where user motivation and sustained interaction are critical.

IV. CONCLUSION

The evaluation using experience user testing for each gamification feature. most respondents felt that the points, leaderboards, and challenge & quest elements provided high perception, satisfaction, motivation and pleasure in using the digital library system. By implementing gamification elements such as points, leaderboards, and quest & challenges, the University of Bhinneka Nusantara's digital library can enhance user engagement. The system is designed with the intention to enhance user engagement and loyalty, which may be evaluated through future deployment and longitudinal observation. Furthermore, by collecting data on user activities (e.g., frequently read books and completed challenges), the library can develop a better recommendation system, helping users find books or articles relevant to their preferences.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the University of Bhinneka Nusantara for the support and facilities provided during this research. Special thanks are also extended to all respondents who participated in the user experience testing of the digital library system. Their feedback and involvement were essential in evaluating the effectiveness of the proposed gamification elements. Lastly, the authors acknowledge the valuable input from reviewers, which helped improve the quality of this paper.

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