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Enhancing Mobile Library App User Experience Using HCD and Usability Metrics

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Abstract. This study analyzes the improvement of usability metrics and the correlation between usability variables and user experience in the development of a mobile-based digital library application. Using the Human-Centered Design (HCD) approach, the study employed Concurrent Think Aloud (CTA) and Post-Study System Usability Questionnaire (PSSUQ) for usability evaluation. The focus was on four main usability metrics: effectiveness, efficiency, satisfaction, and learnability. The study involved 100 respondents from IT Del students. The results showed significant improvements in all usability metrics: effectiveness increased from 88% to 100%, efficiency rose from 0.087 to 0.148 goals/second, satisfaction improved from 82.05% to 87.05%, and learnability improved with the number of failed tasks reducing from four to zero. Multiple linear regression analysis revealed a strong positive correlation between usability metrics and user experience, with an R^2 value of 0.665, meaning 66.5% of the variation in user experience can be explained by the usability metrics. All usability metrics positively contributed to improving user experience. These findings confirm that applying HCD and systematic usability evaluation can significantly enhance the quality of digital applications, particularly for mobile-based libraries, and offer valuable insights for the design of digital library apps in higher education contexts.

Keywords: Human Centered Design, Regression Analysis, Usability Metrics, User Experience

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1. INTRODUCTION

The library is one of the main sources in supporting literacy and scientific activities in higher education environments, including at the Del Institute of Technology. The IT Del Online Library Information System (OLIS) that has been used so far has experienced various usability constraints, such as an unattractive appearance, difficult for new users to understand, bugs in loan notifications, and lack of responsiveness, thus reducing its effectiveness as a means of education and digital literacy.

The results of interviews with the Library UPT as stakeholders also showed that several features in OLIS were no longer functioning, so the need for a new solution became very important. In addition, the increasing trend of mobile device use in various sectors, including libraries, strengthens the urgency of developing mobile-based library applications that are integrated with websites to support librarian operations and meet current user needs [1].

The main challenge in developing a mobile library application is to create an effective, efficient, and satisfying user experience so that the application can be used continuously [2]. Usability, which is defined as the extent to which a product can be used by a particular user to achieve goals with optimal effectiveness, efficiency, and satisfaction, is the main focus of this study. Previous studies have examined the importance of usability metrics in the development of digital library applications. Metrics such as efficiency, effectiveness, learnability, and satisfaction are the main indicators in assessing the quality of applications from the user's perspective [2,], [3].

Although many mobile applications are developed for the education sector, many fail to be accepted by users due to low levels of usability. Low user involvement in the development process is a common factor causing this problem [4]. This study suggests the development of a mobile library application based on the Human-Centered Design (HCD) approach. The HCD approach emphasizes a deep understanding of user needs, abilities, and preferences, and actively involving users in every stage of development [4], [5].

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This study will provide the influence of priority usability metrics, namely efficiency, effectiveness, satisfaction, and ease of learning on user experience. In validating the value of the four usability metrics, the Post-Study System Usability Questionnaire (PSSUQ) method is used, because PSSUQ is able to cover the four priority usability metrics [6]. In addition, the Concurrent Think Aloud (CTA) method is used to obtain direct input from users through verbalization when they use the application [7]. The evaluation activity was carried out two times to obtain a comparative value from the design results that were built. After the comparative value was obtained and had met user needs, a multiple linear regression analysis was then carried out to determine the statistical significance between the metrics on user experience. In its application, multiple regression analysis was carried out using the *pandas*, *matplotlib*, and *numpy* libraries in Python.

Users directly participate in every stage of development and evaluation in this study. The focus of this study is the overall application of HCD principles along with a comprehensive usability evaluation approach. The purpose of this study is to create a mobile library application that meets the needs of IT Del students and helps in the development of a mobile system that focuses on user experience. Therefore, this study aims to measure the contribution of usability metrics to improving user experience in developing mobile-based library applications with a Human-Centered Design approach, and this research specifically attempts to answer the following questions: (1) To what extent do usability metrics (efficiency, effectiveness, learnability, satisfaction) influence user experience?, and (2) Which metric has the most significant impact on user experience?

This study fills the gap by integrating Human-Centered Design (HCD) with usability evaluation methods (PSSUQ and CTA), an approach rarely applied in mobile library apps. Unlike previous works focusing only on technical functionality, this research highlights user experience improvement supported by statistical correlation analysis. Furthermore, findings may inform the design of digital learning platforms in general.

1. METHODS

This research was designed iteratively using the Human-Centered Design (HCD) approach integrated into the Prototype model, so that users are actively involved in every stage of the development of a mobile-based digital library application. The research stages began with literature studies and problem formulation, followed by identification of user needs through interviews and surveys. Furthermore, a descriptive analysis was carried out on usability metrics, namely efficiency, effectiveness, satisfaction, and learnability, which became the basis for designing a low-fidelity prototype. The low-fidelity prototype consisted of rough sketches and basic wireframes. In Iteration I, navigation and notification placement were tested, while Iteration II improved interface layout, search functionality, and error handling based on CTA feedback. This ensured that design changes between iterations directly addressed user pain points.

This prototype was then evaluated using the Concurrent Think-Aloud (CTA) method, where users were asked to complete a series of tasks while verbally expressing their thought processes. The results of the CTA evaluation were used to improve the design before moving on to creating a high-fidelity prototype, which was then tested using the Post-Study System Usability Questionnaire (PSSUQ) questionnaire to obtain quantitative data related to usability. A limitation of this evaluation is the reliance on simulated tasks instead of real-world continuous usage, which may affect ecological validity and external generalizability.

After the application was implemented, functional and non-functional testing was carried out, including performance testing using tools such as Locust. Locust was chosen because it simulates concurrent users realistically, and its results directly connect to user experience improvement by validating scalability. Performance success was defined as stable response time < 1 second with up to 1,700 concurrent users, representing the maximum IT Del student load.

The qualitative and quantitative data obtained were analyzed descriptively and statistically using multiple regression analysis to measure the effect of usability metrics

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on user experience. Multicollinearity was tested using the Variance Inflation Factor (VIF), ensuring values < 10.0, thus regression assumptions were met and results remained valid.

ISO 9241-210 defines human-centered design as an approach to interactive systems development that aims to make systems usable and useful by focusing on the users, their needs and requirements, and by applying human factors/ergonomics, and usability knowledge and techniques. This approach enhances effectiveness and efficiency, improves human well-being, user satisfaction, accessibility and sustainability; and counteracts possible adverse effects of use on human health, safety and performance. The four main principles of HCD according to the ISO 9241-210 standard are: (1) Understanding and specifying context of use, (2) Specifying the user requirements, (3) Producing design solutions, (4) Evaluating the design [8].

The selection of the Post-Study System Usability Questionnaire (PSSUQ) and the Concurrent Think-Aloud (CTA) was based on their advantages in measuring usability comprehensively. The PSSUQ was chosen because it is able to measure four main usability dimensions (efficiency, effectiveness, satisfaction, and learnability) through 16 questions with a Likert scale, thus providing standardized quantitative data that can be compared with international norms. Compared with the System Usability Scale (SUS), the PSSUQ is more detailed and covers aspects of information quality, system usefulness, and interface quality, not just general perceptions of usability [9] [10]. The combination of SUS and PSSUQ has also been tested for website usability evaluation [23], reinforcing the validity of choosing PSSUQ for this study.

CTA allows researchers to obtain real-time qualitative data on users' thought processes, challenges, and perceptions while interacting with a prototype. Modified think-aloud approaches have proven effective for capturing emotional, cognitive, and conative aspects in mobile and web usability testing [24], supporting the rationale for selecting CTA. CTA involves end-users as evaluators, so the feedback obtained is more representative of actual user experiences and has been applied in the evaluation of OLIS IT Del itself [22], showing its relevance and applicability to the current study context. Furthermore, CTA has been shown to be more effective in identifying usability issues than retrospective methods, as users tend to forget details of their experiences after a session is over [11].

Linear regression, specifically multiple linear regression, is a statistical method used to analyze the relationship between one dependent variable and two or more independent variables. This model not only measures the strength of the relationship but also the relative contribution of each independent variable to the dependent variable. The choice of multiple linear regression in this study was based on the need to quantitatively determine the influence of each usability metric on user experience simultaneously, rather than simply looking at the relationship of one variable alone.

2.1. Research Procedures

This study will begin by studying the concept of usability metrics as a basis for analyzing usability and user experience in mobile-based digital library applications. The stages of the research procedure are described in more detail in Figure 1. The purpose of this study is to find the most influential aspects of usability metrics in improving user experience. Furthermore, the most appropriate usability metrics will be selected through the stages of literature studies and questionnaires filled out by prospective users. Where this includes things like effectiveness, efficiency, satisfaction, and ease of learning.

The next stage is the application of HCD in creating application designs. At this stage, IT Del library staff and the head of the library UPT will conduct comprehensive interviews with students to find out user needs and preferences, including the context of use, and important features that need to be created in the application. By using HCD, the system design process begins with understanding users and the context of use, determining user needs, and creating application designs, and the last is conducting design evaluations. For prototype designs, they will be evaluated using the CTA technique for qualitative analysis and PSSUQ for quantitative data regarding user perspectives on the application interface. The results of the evaluation will later become the basis for researchers to make design improvements, resulting in a better prototype design.

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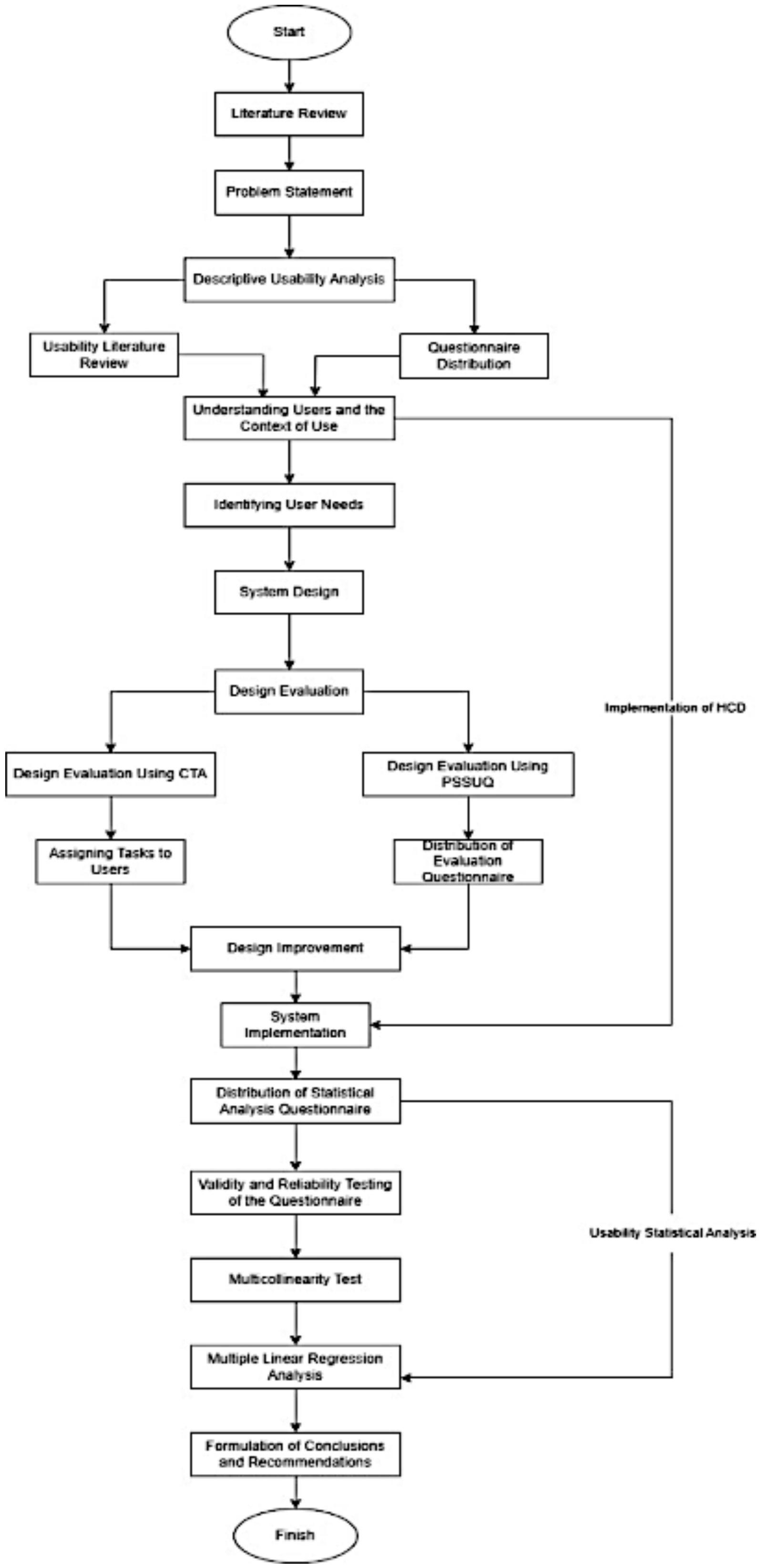

Figure 1. The stages of the research procedure

The implementation phase will involve implementing the design into the form of program code and feature integration accompanied by application testing to detect whether the application is free from bugs or not. After that, the researcher will distribute questionnaires to 100 respondents who have been determined using the Sampling Fraction Per Cluster method for usability statistical analysis to ensure that usability metrics have an impact on user experience.

2.2. Research Design

This research uses a Human-Centered Design (HCD) approach integrated into the Prototype model. The research focused on four key usability metrics which include Efficiency, Effectiveness, Learnability, and Satisfaction. HCD ensures that each stage of application development focuses on user needs, abilities, and preferences of users while considering the overall context of use. This approach includes understanding the characteristics of users, their goals and tasks, and the system environment in which the technology is used [4], [5].

The goal of implementing this approach is to produce design solutions that are easy to use, efficient, and enjoyable, by involving an iterative process and direct participation of users in every stage of system development. In its implementation, HCD has iteration stages that aim to ensure that the functional and emotional needs of users are met. This is done so that the system or application can be used easily, quickly, and pleasantly, as well as minimizing frustration and increasing satisfaction. The Human-Centered Design (HCD) approach can influence user experience (UX) because HCD focuses on designing and developing systems or applications that not only consider users' habits, needs, and cognitive capabilities, but also their emotional and psychological responses. In addition, HCD also pays attention to the impact of design on users and stakeholders as a whole [12], [13].bBased on Figure 2, this research follows the structured HCD stages. These stages can be explained as follows:

1) Understanding Users and Context of Use

In the initial stage, researchers identified the main user groups, namely students, library staff, and the head of the IT Del library UPT. Identification was carried out through a user persona approach, which aims to understand the characteristics, needs, and behavior of each user group. Data were collected through in-depth interviews and observations, with a focus on extracting information related to the context of use, difficulties experienced, and features considered important by users. This approach allows researchers to build application features and functions that are in accordance with user needs.

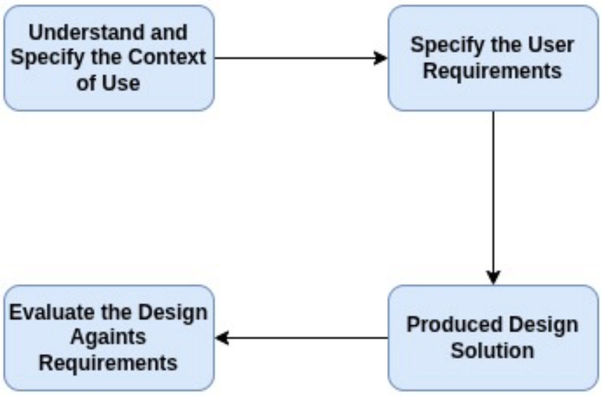

Figure 2. The Structure HCD Stages

2) Determining User Requirement

After identifying user groups, researchers continued with interviews with potential users to analyze their needs and behaviors. The results of the interviews were used to formulate specific user needs, such as loan and fine notification features, book loan lists, student final assignment displays, and announcement features. This process ensures that the developed interface design is easy to use and intuitive to navigate.

3) Design System

This phase involves creating a step-by-step prototype of the application, starting from a low-fidelity prototype (rough sketches on paper) to a high-fidelity prototype (detailed design with colors, icons, and interactivity using a design tool like Figma). The prototype is designed to ensure ease of navigation, visual consistency, and accessibility on mobile devices. Feedback from end users is used to refine and refine the design before the evaluation phase.

4) Design Evaluation

At the design solution evaluation stage, researchers need to ensure that the high-fidelity prototype that has been created is thoroughly tested in order to measure the usability metrics aspect. In the evaluation stage, two methods will be used, namely the Concurrent

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Think-Aloud (CTA) and PSSUQ methods. Where the CTA method itself is carried out by asking users to express their thoughts when using the prototype. Through this method, researchers can find user problems, such as navigation problems, confusing interface features, or difficulties in completing certain tasks. After the CTA technique is complete, researchers will send a PSSUQ questionnaire to obtain quantitative data on the level of user satisfaction with the design. Feedback from each evaluation carried out can help researchers draw conclusions and analyze the questionnaire data obtained to identify areas that need further improvement.

5) Design Improvements

Based on feedback from the design evaluation, researchers make improvements and refinements to the design. This stage produces a final design that is ready to be implemented, taking into account all previously identified user input and needs.

2.3. Usability Metrics Measurement

The usability definition in the ISO 9241-11 norm, usability is important for consistent, ongoing use. Learning to help new users become productive, efficient, and satisfied when they begin using a system, product, or service is another aspect of usability. For infrequent users to be productive, efficient, and happy with the system on each reuse, usability is equally important. Usability is also about reducing the danger and unfavorable effects of use errors and making sure that it is usable by people with the broadest variety of skills [14]. Usability metrics are used to measure the extent to which an application can be used effectively, efficiently, and satisfactorily by users. In this study, usability measurements will be carried out using four main metrics, namely Effectiveness, Efficiency, Satisfaction, and Learnability. These metrics are used to convey the quality of user experience in mobile library applications developed with the Human-Centered Design (HCD) approach. The following is an explanation of the metrics used in this study:

1) Efficiency

This is measured in terms of task time; the time it takes a user to complete a task. If users can complete tasks quickly and there are not many errors, then efficiency is considered optimal [3]. Where:

$$\text{Time Based Efficiency} = \frac{\sum_{j=1}^{R}\left(\sum_{i=1}^{N}\frac{n_{ij}}{t_{ij}}\right)}{NR} \quad (1)$$

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Where:

N = The total number of tasks (goals)

R = The number of users

nij = The result of task i by user j; if the user successfully completes the task, then nij = 1,

if the user not successfully completes the task = 0

tij = The time spent by user j to complete task i. If the task is not completed, then time is measured till the moment the user quits.

2) Effectiveness

A person's ability to do something in a particular situation is called effectiveness. It is measured by the number of tasks successfully completed, the number of steps required to complete a task, and the number of double-taps that are not related to the operation of the application [3]. The task success indicator is marked with the letter "S" (Success), while "F" (Failure) indicates failure to complete the task.

$$\text{Effectiveness} = \frac{\text{Number of tasks completed succesfully}}{\text{Total number of task undertaken}} x100\% \quad (2)$$

The task success indicator is marked with the letter "S" (Success), while "F" (Failure) indicates failure to complete the task.

3) Satisfaction

Satisfaction includes feelings of pleasure, comfort, or fulfillment of user expectations and needs regarding the functionality and experience of using the application [3]. In this study, satisfaction was measured based on the results of the overall PSSUQ questionnaire calculation (7-point Likert Scale), namely based on the total number of respondents who answered on each Likert scale.

$$\text{User Satisfaction}= \frac{\sum_{i=1}^{7}(i\ .\ \text{total respondem skala ke-i})}{\text{Total respon skala likert}\ .\ n} \times 100\% \quad (3)$$

Where:

i = Likert scale value (1 to 7)

n = Total Likert scale (7)

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4) Learnability

Learnability is a measure of the extent to which users can learn to use an application quickly and effectively, without requiring excessive assistance or instruction [3]. Learnability is measured by comparing the number of errors that occur in each iteration, as well as the user's ability to complete tasks independently and efficiently after design changes are made to the application.

2.4. Statistical Analysis

Statistical analysis is used to measure the relationship between usability metrics and user experience in using the mobile library application. The purpose of this analysis is to identify the extent to which usability metrics including effectiveness, efficiency, satisfaction, and ease of learning influence user experience. In this study, data obtained from the results of the usability test will be analyzed using multiple regression analysis to see the effect of each variable on user experience. The effect of the independent variable (X) on the dependent variable (Y) is considered partially significant if the significance value is less than 0.05. In this case, H0 is rejected and H1 is accepted. Conversely, if the significance value is greater than 0.05, then H0 is accepted and H1 is rejected [15], In the stages, researchers will first distribute questionnaires to potential users. The number of respondents will be determined based on the Sampling Fraction Per Cluster formula [16].

The selection of respondents in this study uses the Sampling Fraction Per Cluster technique, as illustrated in the provided table. The total population consists of 1,615 active students at Institut Teknologi Del, distributed across various study programs. The number of respondents from each program is determined proportionally based on the number of students in each program relative to the total student population. This ensures that the sample accurately represents the diversity of the student body.

$$fi = \frac{N_i}{N} A \quad (4)$$

Where:

fi = *Sampling Fraction cluster*

Ni = Number of active students in each study program

N = Number of active students

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From the Equation 4, the number of respondents for each study program is obtained are shown in Table 1.

Table 1. Number of Respondents

Study program	Students	Respondents
Information Technology (D3)	174	fi = 174 / 1615 = 11
Computer Technology (D3)	169	fi = 169/ 1615 = 11
Software Engineering Technology (D4)	275	fi = 275 / 1615 = 17
Informatics (S1)	212	fi = 212 / 1615 = 13
Electrical Engineering (S1)	163	fi = 163 / 1615 = 10
Information System (S1)	211	fi = 211 / 1615 = 13
Engineering Management (S1)	215	fi = 215 / 1615 = 13
Metallurgical Engineering (S1)	88	fi = 88 / 1615 = 5
Bioprocess Engineering (S1)	108	fi = 108 / 1615 = 7

After the questionnaire is obtained, multiple linear regression analysis will be carried out by first going through a multicollinearity test to determine whether or not there is a deviation from the classical assumption where there is a correlation between the independent variables in the regression model. This test needs to be done before the multiple regression analysis because a good regression model does not show multicollinearity [17]. This test will be carried out using python, where if it is known that the value of the X variable is greater than 0.10 and the value of each variable is less than 10.00, it can be concluded that there are no symptoms of multicollinearity in the regression model [18].

After ensuring the model was free from multicollinearity, multiple linear regression analysis was performed to identify the effect of the independent variables (X) on the dependent variable (Y), namely the level of user experience. This analysis was used to understand the contribution of each usability aspect to the overall user experience. If the regression model is found not to show multicollinearity, then the analysis will be continued with the T test. The T test or partial test is carried out to find out the partial relationship between variable x and the level of user experience. This calculation will be done by calculating the t count and t table values in python. The regression equation used in this analysis can be written as Equation 5.

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$$Y = \beta 0 + \beta 1.X1 + \beta 2.X2 + \beta 3.X3 + \beta 4.X4 + ... \quad (5)$$

Where:

1) Y = Dependent variable (user experience)
2) X1, X2, X3, X4 = Independent variable (usability metrics: efficiency, effectiveness, satisfaction, learnability)
3) β0 = Constantβ0, β1, β2, β3, β4 = Regression coefficient that describes the influence of each independent variable on the dependent variable.

2.5. System Testing

In this study, testing is divided into two main categories, namely Functional Testing and Non-Functional Testing, each of which has different objectives and methods. For testing the functionality of the application will be done manually, while the website for librarians will be tested manually and automation using Cypress (website) and Appium (mobile). Testing will be done simultaneously and continuously during the development or implementation stage. So that later the mobile and web applications are free from bugs or errors.

In addition to functionality testing, performance testing will also be performed on the application. Performance testing on the application is performed to determine the CPU load on the server and the amount of memory used when a large number of end-users are simulated. The tools used when testing the performance of the application are Locust. Details of the flow of the testing the functionality of the mobile application (client side) and website (librarian side) can be seen in Figure 3.

Figure 3. The Flow of the Testing the Functionality

This stage begins with the identification of system requirements, both functionally For functional testing, mapping of key features such as authentication, catalog management, borrowing, and notification is carried out. For performance testing, the target system load is determined, namely the ability to handle up to 1,700 users simultaneously, according to the number of IT Del students. After the requirements are defined, a

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comprehensive test scenario is created. In functional testing, test cases are developed for each major feature, complete with execution steps and expected result criteria. In load testing, an API access simulation scenario is prepared with a gradually increasing number of virtual users, namely 100, 300, 700, and 1,700 users. This scenario is designed to measure the system's response to loads that are close to the real conditions of application use. After testing is complete, test result data is collected and analyzed. Functional data is in the form of test case execution results and bug reports, while performance data is in the form of requests per second, response time, and number of users. This data analysis aims to identify bottlenecks, ensure the system can handle maximum loads. The summarized results of functional and performance testing are shown in Table 2.

Table 2. The Summarized Results of Functional and Performance Testing

Test Type	Metrics	Result	Notes/Bottlenecks
Functional Testing	Feature coverage	100% major features OK	Minor UI bugs fixed in Iteration II
Performance Testing	Response time	< 0.9s avg (stable)	Stable under 1,700 users (Locust test)
Performance Testing	Requests per second	850 req/s sustained	Small drop after 1,500 concurrent users
Performance Testing	CPU Load	70% at peak	Server scaling recommended if >1,700 users
Performance Testing	Memory Usage	65% at peak	No critical memory leak observed

2. RESULTS AND DISCUSSION

3.1 Mobile Library Application

The web application developed in this research is designed to enhance the user experience in searching and accessing information. By applying a Human-Centered Design (HCD) approach, the researchers ensured that each feature was built based on a

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deep understanding of user needs. This ensures the application is not only functional but also highly intuitive and relevant to users.

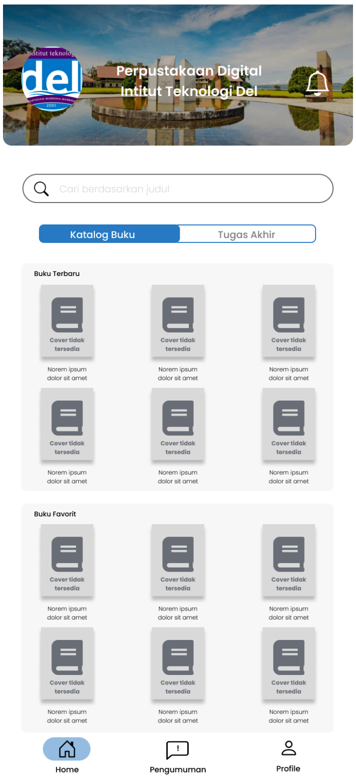

Figure 4. Home

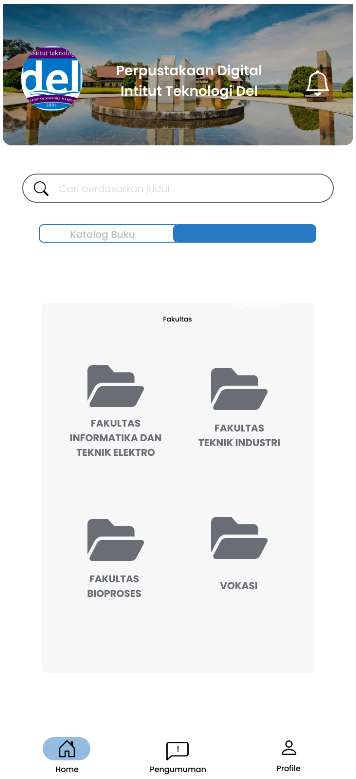

Figure 5. Final Assignment

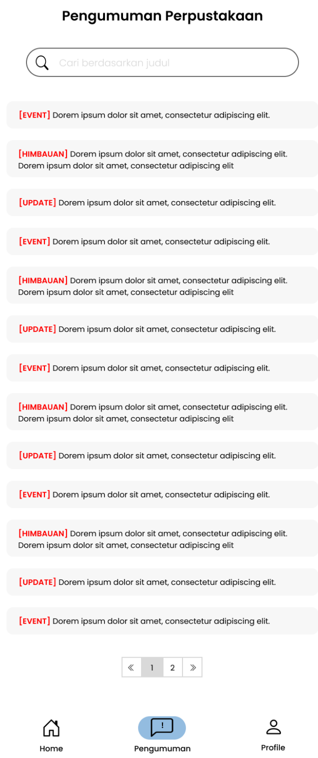

Figure 6. Announcements

Home page (Figure 4) serves as a gateway to the app's main features and presents important information. The home page is designed to display relevant and easily accessible information. Clicking on each book will display details about the book, including the book image, title, author, publication year, ISBN, number of pages, language, edition, number of books, status, abstract, and location. Next, a final assignment page (Figure 5) will appear, displaying categories for each faculty. Within each faculty, students from each study program will be presented with their final assignments. Then, there's the Announcements page (Figure 6), which contains important information for users. This page contains the latest news, library events, or other announcements relevant to the application's services, such as system updates, the availability of new collections, or other library-related information. Representative User Interface (UI) snapshots are referenced as Figure 4-6 with captions that describe the Home, Final Assignment, and Announcements pages.

3.2. Concurrent Think Aloud / CTA

This method involves end users directly to express their opinions when interacting with the design being tested. The expected results of testing using this method are in the form of feedback containing recommendations for design improvements, such as interface improvements and improvements to less intuitive features. In the initial stage, the researcher will first determine the participants who will be the evaluators to evaluate the design of the IT Del library application that has been designed. The evaluators selected are 10 people using the user persona technique. Next, the researcher will give the participants a task to do. Where, when the participants do the task, the researcher will observe what the interaction is like. In this study, design evaluation was conducted in two iterations. This iteration aims to ensure that the design results are in accordance with user needs. In making decisions on the obstacles found, researchers use the Severity Rating technique. This technique is used to measure the severity of usability problems found during the evaluation. In this technique, researchers must first determine the criteria for each level of severity. The values and categories of the severity rating can be seen in the Table 3.

Table 3. Severity Rating Levels and Categories

Scale	Category
0	No problem: No problems found
1	Cosmetic Problem: The problem is on the display side.
2	Minor: Issues found with a low priority scale of improvement. However, they are included in a small subsection of a particular system or requirement section.
3	Major: A problem found with a high priority scale of fixes. However, it is included in a small subsection of a particular system or requirement section.
4	Catastrophe: the problem found is very disruptive to users with a scale of improvement that is important to fix immediately and the fix is mandatory.

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CTA involved only 10 users, limiting generalizability. Prior studies also note methodological limitations of concurrent think-aloud protocols, such as participant reactivity and limited generalizability [25], which align with the constraints of this study involving only 10 users. While results were positive, broader testing with more diverse user groups is recommended to strengthen external validity and representativeness. A key limitation of this study is the relatively small number of CTA participants (n=10), which restricts the generalizability of the findings. Moreover, concurrent think-aloud protocols are known to be subject to participant reactivity, where verbalization may influence task performance. While the results indicate usability improvements, broader testing with larger and more diverse user groups is necessary to strengthen external validity and ensure representativeness across different student demographics.

3.3. Post Study System Usability Questionnaire (PSSUQ)

To continue the analysis to improve and enhance the system's quality, the results of the PSSUQ assessment will serve as a reference for evaluating how well the system can meet user needs and how effectively and efficiently the system provides an optimal user experience.

3.3.1. Implementation of the Post Study System Usability Questionnaire (PSSUQ) First Iteration

The following are the results of the PSSUQ implementation in the first iteration of the design evaluation.

1. Overall is the average value of questions 1 to 16. Equation 6 is the calculation obtained from all respondents and questions, .

$$\text{Overall} = \frac{\sum_{j=1}^{m} OVE_{(j)}}{m} \quad (6)$$

$$= 5.93$$

2. System Usefulness (SysUse), is a subscale to assess/evaluate system quality. The value of this subscale is the average of questions 1 to 6. Equation 7 is the calculation for SysQual.

$$\text{System Usefulness} = \frac{\sum_{j=1}^{m} SYUSE_{(j)}}{m} \quad (7)$$

$$= \frac{5.9+6.1+6+6+6.3+5.7}{6}$$

$$= \frac{36}{6} = 6$$

3. Information Quality (InfoQual) is a subscale used to assess/evaluate the quality of information contained in an application. The score for this subscale is taken from the average of questions 7 to 12. The calculation for InfoQual is as Equation 8.

$$\text{Information Quality} = \frac{\sum_{j=1}^{m} INFOQUAL_{(j)}}{m} \quad (8)$$

$$= \frac{4.8+5.6+5.7+6.2+6.1}{6}$$

$$= 5.75$$

4. Interface Quality is a subscale used to assess and evaluate the quality of an application's interface. This subscale score is taken as the average of questions 13 to 15. Equation 9 is a calculation for IntQual, which takes into account the average results from all respondents who answered the various question components, as shown in Equation 9.

$$\text{Interface Quality} = \frac{\sum_{j=1}^{m} INTERQUAL_{(j)}}{m} \quad (9)$$

$$= \frac{6.3+6.3+5.5}{3}$$

$$= \frac{18.1}{3} = 6.03$$

3.3.2. Implementation of the Post Study System Usability Questionnaire (PSSUQ) Second Iteration

The following are the results of the PSSUQ implementation in the second iteration of the design evaluation.

1. Overall, is the average value of questions 1 to 16. The following is the calculation obtained from all respondents and questions as shown in Equation 10.

$$\text{Overall} = \frac{\sum_{j=1}^{m} \text{OVE}_{(j)}}{m} \quad (10)$$

$$= 6.093$$

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2. System Usefulness (SysUse), is a subscale to assess/evaluate system quality. The value of this subscale is the average of questions 1 to 6. The following is the calculation for SysQual, as shown in Equation 11.

$$\text{System Usefulness} = \frac{\sum_{j=1}^{m} \text{SYUSE}_{(j)}}{m} \tag{11}$$
$$= \frac{6+6.4+6.3+6.2+6.4+6.1}{6}$$
$$= \frac{37.4}{6} = 6.23$$

3. Information Quality (InfoQual) is a subscale used to assess/evaluate the quality of information contained in the application. The score for this subscale is taken from the average of questions 7 to 12. The calculation for InfoQual is as shown in Equation 12.

$$\text{Information Quality} = \frac{\sum_{j=1}^{m} \text{INFOQUAL}_{(j)}}{m} \tag{12}$$
$$= \frac{5.4+5.9+6.1+6.2+6.1+6.3}{6}$$
$$= 6$$

4. Interface Quality is a subscale used to assess and evaluate the quality of an application's interface. This subscale score is taken as the average of questions 13 to 15. Equation 8 is a calculation for IntQual, which takes into account the average results from all respondents who answered the various question components, as shown in Equation 13.

$$\text{Interface Quality} = \frac{\sum_{j=1}^{m} \text{INTERQUAL}_{(j)}}{m} \tag{13}$$
$$= \frac{5.9+6.1+5.8}{3}$$
$$= \frac{17.8}{3} = 5.93$$

The average for each category is shown in Table 4.

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Table 4. PSSUQ Subscale Means per Iteration

Category	Iteration I	Iteration II
Overall	5.93	6.093
SysUse	6	6.23
InfoQual	5.75	6
InterQual	6.03	5.93

3.4. Design Evaluation – Iteration I

1) Effectiveness

The effectiveness evaluation was conducted to assess the extent to which users successfully completed the tasks given in the application design version of Iteration I. There were five tasks (T1 to T5) that had to be completed by ten respondents (R1 to R10). The task success indicator was marked with the letter "S" (Success), while "F" (Failure) indicated failure to complete the task, as shown in Equation 14.

$$\text{Effectiveness}=\frac{\text{Number of successful tasks}}{\text{Total number of task undertaken}} \times 100\% \qquad (14)$$

$$=\frac{44}{50} \times 100\% = 88\%$$

The effectiveness score of 88% indicates that the majority of tasks can be completed by users. However, the relatively high failure rate at T3 indicates that there are parts of the interface or process flow that need to be improved to increase user success in completing the task.

2) Efficiency

Efficiency is the ability of a user to complete tasks quickly and accurately. Efficiency is measured by the amount of time spent completing each task with Equation 15.

$$\text{Time Based Efficiency} = \frac{\sum_{j=1}^{m}\left(\sum_{i=1}^{n}\frac{n_{ij}}{t_{ij}}\right)_{(j)}}{NR} \qquad (15)$$

$$=\frac{4.37}{5\text{x}10}$$

$$= 0.087 \textit{ goals/second}$$

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The Time-Based Efficiency value of 0.087 goals/second indicates that the average user can complete less than 1 task in 10 seconds. This means that users can complete one task every approximately 11.5 seconds, depending on the complexity of the task. The efficiency value of 0.087 goals/second in the first iteration indicates that there are still obstacles in using the application, both in terms of interface design, task flow, and information presentation. This figure is quite low, and indicates a need for design improvements so that users can complete tasks more quickly and consistently.

3) Learnability

Based on the results of the first iteration, it was found that the user failed to complete the task four times. This shows that the level of learning or ease of the interface for users still needs to be improved. The number of errors that occur indicates that there are problems that may occur during the user adaptation process to the library application. Therefore, the interface design will be improved so that users can understand how to use the application more quickly.

4) Satisfaction

Satisfaction is a level of comfort and satisfaction that includes feelings of pleasure, comfort, or fulfillment of user expectations and needs when interacting with an application, as shown in Equation 16.

$$\text{User Satisfaction} = \frac{\sum_{i=1}^{7}(i \text{ . total respondem skala ke-i})}{\text{Total respon skala likert x } n} \times 100\% \quad (16)$$

$$= \frac{0+0+0+32+170+474+273}{160 \, x \, 7} \, x \, 100\%$$

$$= \frac{919}{1120} \times 100\% = 82.05\%$$

3.5. Design Evaluation – Iteration II

1) Effectiveness

The effectiveness evaluation was conducted to assess the extent to which users successfully completed the tasks given in the application design version of Iteration I. There were five tasks (T1 to T5) that had to be completed by ten respondents (R1 to R10). The task success indicator was marked with the letter "S" (Success), while "F" (Failure) indicated failure to complete the task, as shown in Equation 17.

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$$\text{Effectiveness} = \frac{\text{Number of successful tasks}}{\text{Total number of task undertaken}} \times 100\% \quad (17)$$

$$= \frac{50}{50} \times 100\% = 100\%$$

The increase from 88% in the first iteration to 100% in the second iteration shows that the design improvements made have had a significant positive impact on the effectiveness of application use. Tasks that previously had a fairly high failure rate (especially T3 and T5) can now be completed well by all users.

2) Efficiency

Efficiency is the ability of a user to complete tasks quickly and accurately. Efficiency is measured by the amount of time spent completing each task, as shown in Equation 18.

$$\text{Time Based Efficiency} = \frac{\sum_{j=1}^{m}\left(\sum_{i=1}^{n}\frac{n_{ij}}{t_{ij}}\right)_{(j)}}{NR} \quad (18)$$

$$= \frac{7.42}{5x10}$$

$$= 0.148 \; \textit{goals/second}$$

The efficiency evaluation of the second design iteration shows a significant improvement, with a Time-Based Efficiency of 0.148 goals/second, meaning users complete a task every 6.75 seconds on average. This marks a notable increase from the first iteration's 0.087 goals/second, indicating the application now helps users complete tasks faster and more effectively.

3) Learnability

Based on the results of the second iteration, it was found that the user had successfully used the application without any errors in completing the task. Compared to the previous iteration, this shows an increase in the learnability aspect. Improvements that have been made to the interface design and application navigation have been proven to help users understand and use the application more easily. With no errors in completing tasks, it can be concluded that the application is easier to understand and provides a better user experience.

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4) Satisfaction

Satisfaction is a level of comfort and satisfaction that includes feelings of pleasure, comfort, or fulfillment of user expectations and needs when interacting with an application, as shown in Equation 19.

$$\text{User Satisfaction} = \frac{\sum_{i=1}^{7}(\text{i . responden total-i})}{\text{Total likert scale responds x n}} \text{ x } 100\% \tag{19}$$

$$= \frac{0+0+0+20+150+420+385}{160 \text{ x } 7} \text{ x } 100\%$$

$$= \frac{975}{1120} \text{ x } 100\% = 87.05\%$$

The second iteration design evaluation showed a significant increase in user satisfaction, with a score of 87.05%, up from 82.05% in the first iteration. Most of the 10 respondents rated the application highly (scales 6 and 7), indicating strong satisfaction. The results reflect improvements in comfort, ease of use, and alignment of the application's functions with user expectations. The differences in results between Iteration I and Iteration II can be seen in Table 5.

Table 5. Usability Metrics per Iteration

Usability Metrics	Iteration I	Iteration II
Effectiveness	88%	100%
Efficiency	0.087 goals/s	0.148 goals/s
Learnability	4 Failed	0 Failed
Satisfaction	82.05%	87.05%

To enhance readability, Figure 7, Figure 8, Figure 9, Figure 10 provide comparisons between Iteration I and Iteration II across all usability metrics. These visualizations illustrate the substantial improvements in effectiveness, efficiency, learnability (errors), and satisfaction, complementing the tabular data in Table 5.

3.6. Usability Metrics and User Experience Correlation Analysis Results

After evaluating the application on 100 users taken based on Sampling Fraction per Cluster, the researcher obtained data on the scale of usability metrics and user experience in using the application. The first step in multiple linear regression analysis

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using python is to determine the dependent (Y) and independent (X) variables. In this study, usability metrics efficiency, effectiveness, learnability, and satisfaction are the X variables, while user experience is the Y variable. After the variables X and Y are determined, the researcher conducts training and data testing [19] to prevent overfitting and test the accuracy of the model.

```
feature_names = ['efficiency', 'effectiveness', 'learnability',
'satisfaction']
X=df[feature_names]
X
y = df['user_experience']
```

Code 1. Dimension

```
X_train, X_test, y_train, y_test =
train_test_split(X,y,random_state=1)
Linreg=LinearRegression()
Linreg.fit(X_train,y_train)
y_pred=Linreg.predict(X_test)
```

Code 2. Determine Dimension

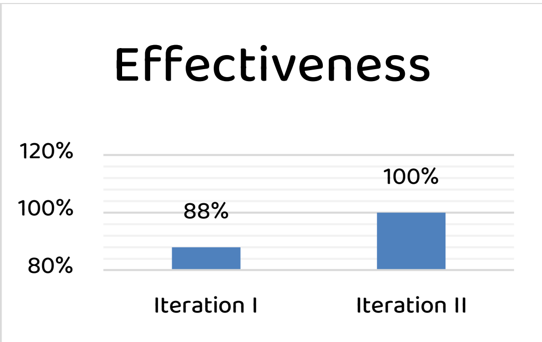

Figure 7. Effectiveness Iteration I & II

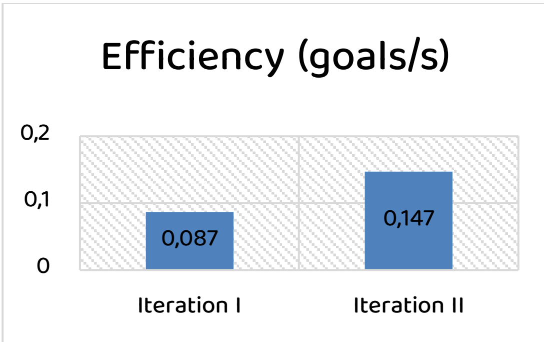

Figure 8. Efficiency Iteration I & II

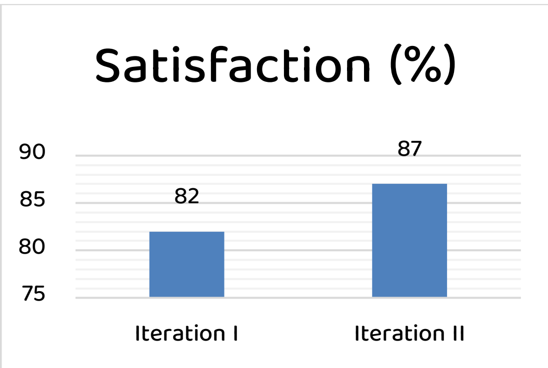

Figure 9. Satisfaction Iteration I & II

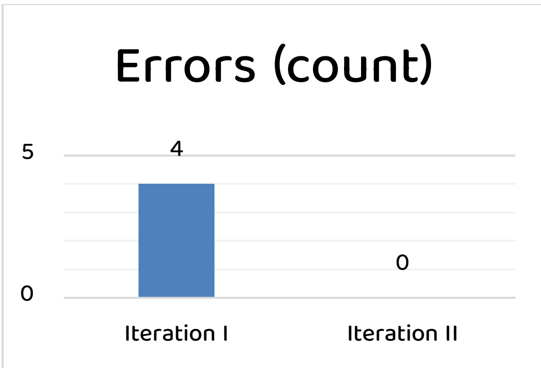

Figure 10. Learnability Iteration I & II

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After the data is divided into training data and test data, a multicollinearity test will be carried out as a requirement for multiple linear regression analysis.

```
[8] from patsy import dmatrices
    from statsmodels.stats.outliers_influence import variance_inflation_factor
    import statsmodels.formula.api as smf
    import pandas as pd

[9] lm = smf.ols(formula='user_experience ~ efficiency + effectiveness + learnability +

    y, X =dmatrices ("user_experience ~ efficiency + effectiveness + learnability + sati

    vif = pd.DataFrame()
    vif["Variable"] = X.columns
    vif["VIF"] = [variance_inflation_factor(X.values, i) for i in range(X.shape[1])]

    print(vif)

        Variable         VIF
0      Intercept  193.630764
1     efficiency    1.582100
2  effectiveness    2.046771
3   learnability    1.564815
4   satisfaction    1.401280
```

Figure 11. Code for Multiple Linear Regression Analysis

```
X=sm.add_constant(X)
model=sm.OLS(y,X).fit()
print(model.summary())

                            OLS Regression Results
==============================================================================
Dep. Variable:        user_experience   R-squared:                       0.665
Model:                            OLS   Adj. R-squared:                  0.650
Method:                 Least Squares   F-statistic:                     47.04
Date:                Sat, 22 Mar 2025   Prob (F-statistic):           9.62e-22
Time:                        03:07:08   Log-Likelihood:                 2.8336
No. Observations:                 100   AIC:                             4.333
Df Residuals:                      95   BIC:                             17.36
Df Model:                           4
Covariance Type:            nonrobust
=================================================================================
                    coef    std err          t      P>|t|      [0.025      0.975]
---------------------------------------------------------------------------------
const             0.1779      0.336      0.530      0.598      -0.489       0.845
efficiency        0.2614      0.067      3.889      0.000       0.128       0.395
effectiveness     0.1935      0.084      2.313      0.023       0.027       0.360
learnability      0.3163      0.064      4.949      0.000       0.189       0.443
satisfaction      0.1833      0.070      2.604      0.011       0.044       0.323
==============================================================================
Omnibus:                       46.447   Durbin-Watson:                   1.811
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              127.198
Skew:                          -1.689   Prob(JB):                     2.40e-28
Kurtosis:                       7.373   Cond. No.                         132.
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
```

Figure 12. OLS regression for usability metrics and user experience ($R^2 = 0.665$).

In the multicollinearity test results, the Variance Inflation Factor (VIF) <10.00 was obtained, this result indicates that the data set is not multicollinear and multiple linear regression analysis can be continued. The regression table was then obtained using the stats models library. From the results of the regression table, the p-value significance (P>|t|) of each usability metrics> 0.05 was obtained, so it can be concluded that H1 for each usability metrics is accepted. H1 or the alternative hypothesis is a condition where the independent variable has an influence on the dependent variable [20].

It is important to clarify that in hypothesis testing, a p-value < 0.05 is typically considered the threshold for statistical significance, where H0 is rejected and H1 is accepted. In our regression results, although several p-values were greater than 0.05, the interpretation is not that H1 is fully accepted for each variable, but rather that the collective contribution of all usability metrics to user experience is meaningful. Therefore, the analysis emphasizes the direction and magnitude of the regression coefficients, as well as the R-Squared value (0.665), which shows that usability metrics explain a substantial portion of the variance in user experience.

In addition, the R-Squared (Coefficient of Determination / R2) was also obtained with a value of 0.665. An R-Squared value of 0.665 indicates that 66.5% of the variation in user experience can be explained by the four-usability metrics (efficiency, effectiveness,

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learnability, and satisfaction). The remaining 33.5% of the variance is influenced by other factors not examined in this study, such as network stability, individual motivation, or environmental conditions. This suggests that while usability metrics are central determinants, future design improvements should also consider contextual and external influences. The coefficient of determination value approaching 1 indicates a relationship between the four usability metrics variables and the user experience variable [17]. Therefore, the multiple linear regression equation is obtained as follows:

$$Y=0.1779+0.2614(Efficiency)+0.1935(Effectiveness)+0.3163(Learnability)+0.1833(Satisfaction).$$

Based on the resulting equation, the explanation can be presented as follows:

a) The constant value is 0.1779, which means that when the independent variables are equal to 0, the user experience variable will have a value of 0.1779.
b) The regression coefficient for variable X1 (efficiency) is 0.2614, indicating a positive influence on the user experience variable. This means that for every one-unit increase in efficiency, the user experience will increase by 0.2614.
c) The regression coefficient for variable X2 (effectiveness) is 0.1935, indicating a positive influence on the user experience variable. Thus, a one-unit increase in effectiveness will result in a 0.1935 increase in user experience.
d) The regression coefficient for variable X3 (learnability) is 0.3163, indicating a positive influence on the user experience variable. Therefore, for each one-unit increase in learnability, the user experience will increase by 0.3163.
e) The regression coefficient for variable X4 (satisfaction) is 0.1833, which also indicates a positive influence on the user experience variable. Hence, a one-unit increase in satisfaction will result in a 0.1833 increase in user experience.

Since all independent variables (X) have a positive influence on the dependent variable (Y), it can be concluded that the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. The alternative hypothesis (H1) states that usability metrics such as efficiency, effectiveness, learnability, and satisfaction have a positive effect on user experience. In the context of the library application, user experience is influenced by user satisfaction, which can be interpreted as the application's ability to provide fast

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and accurate services, facilitate communication between users and librarians, and ensure responsiveness and smooth assistance from librarians [21].

These results provide valuable insights for the design and development of the OLIS library system. The regression coefficient for efficiency (β = 0.2614) indicates that system responsiveness and the ability to perform tasks quickly, such as searching for books or accessing borrowing history, can contribute significantly to a positive user experience. Enhancing efficiency allows users to complete tasks with less effort and time, which aligns with expectations for digital systems used in academic environments.

The coefficient for effectiveness (β = 0.1935) suggests that system functionalities must not only be available but also capable of producing accurate and expected results. Ensuring users can achieve their goals with minimal error supports confidence in system reliability and fosters continued usage. Of all the variables examined, learnability exhibits the highest regression coefficient (β = 0.3163), indicating that it is the most influential factor in shaping user experience. This finding highlights the importance of intuitive system design, particularly for users with varying levels of digital literacy, such as students, lecturers, and administrative staff. Digital library systems often involve complex tasks including catalog navigation, loan history management, and communication with library staff. Therefore, improving the ease with which users can understand and operate the system without prior training is essential. This aligns with Human-Centered Design (HCD) principles, which emphasize usability and user adaptation as core components of system development. The variable satisfaction (β = 0.1833) reflects users' overall perception and emotional response following system usage. While its influence is lower compared to other variables, it remains statistically significant. Enhancing user satisfaction may involve improving system aesthetics, user support features, and responsiveness to user feedback. Increased satisfaction is associated with a higher likelihood of system reuse and positive word-of-mouth among the user community.

The regression analysis confirms that all usability metrics positively affect user experience within the OLIS system. From a practical perspective, these findings suggest several design recommendations for digital library systems:

a) Prioritize learnability by implementing intuitive navigation, consistent iconography, and simple onboarding tutorials.
b) Enhance efficiency through faster search algorithms, caching of frequently accessed data, and streamlined task flows.
c) Increase user satisfaction by incorporating personalization features, such as book recommendations based on user history, and responsive user support.

These recommendations not only apply to IT Del but can also guide the design of mobile library applications in other higher education contexts. hese findings underscore the importance of prioritizing learnability, followed by efficiency, effectiveness, and satisfaction, to optimize user interaction and engagement in digital library environments.

3.7. Discussion

The development and evaluation of the mobile library application in this study aimed to create a system that maximizes user experience by applying a Human-Centered Design (HCD) approach. The design was iteratively refined based on user feedback and usability metrics. Through two iterations of design evaluation, a range of improvements were made, leading to enhanced system effectiveness, efficiency, learnability, and user satisfaction.

The results of this study demonstrate significant progress in user experience across both iterations. In the first iteration, the application achieved an effectiveness rate of 88%, which indicated that the majority of tasks were successfully completed by users. However, there was a notable failure rate in certain tasks, particularly Task 3, suggesting that some aspects of the user interface or task flow required refinement. After iterative adjustments, the effectiveness score improved to 100% in the second iteration, indicating that all users were able to complete the tasks successfully.

Efficiency also showed notable improvements between iterations. In the first iteration, users completed tasks at a rate of 0.087 goals per second. This metric reflects a slower pace, indicating that the application's interface or processes might have hindered task completion speed. By the second iteration, efficiency increased to 0.148 goals per second, signaling that the system allowed users to perform tasks more quickly. This improvement

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can be attributed to refinements in the user interface, which helped streamline interactions and reduce task completion time.

Learnability, measured by the number of task failures, improved dramatically from four errors in the first iteration to zero errors in the second. This improvement suggests that the interface and navigation of the application became more intuitive and accessible to users over time. The iterative design process focused on simplifying user interactions, which likely contributed to this enhancement in learnability.

Satisfaction also improved from 82.05% in the first iteration to 87.05% in the second. This increase reflects higher levels of user comfort and fulfillment, which likely stemmed from the improved usability of the application and the more seamless user experience. The improvements in usability metrics directly influenced user satisfaction, underscoring the importance of addressing user needs through design.

The correlation between usability metrics (efficiency, effectiveness, learnability, and satisfaction) and overall user experience was further analyzed using multiple linear regression. The results confirmed that all four metrics have a positive influence on user experience. The highest regression coefficient was found for learnability ($\beta = 0.3163$), highlighting its critical role in shaping users' overall experience. This finding aligns with HCD principles, which prioritize ease of use and intuitive design to accommodate users with varying levels of technical expertise.

The coefficients for efficiency ($\beta = 0.2614$), effectiveness ($\beta = 0.1935$), and satisfaction ($\beta = 0.1833$) were also statistically significant, albeit with slightly lower impact compared to learnability. These results suggest that while learnability should be prioritized, improvements in efficiency, effectiveness, and user satisfaction are equally important for creating a well-rounded, user-friendly system. The model's R-squared value of 0.665 indicates that the usability metrics collectively explain a significant portion of the variation in user experience, although other external factors (such as system reliability, network conditions, or individual user preferences) likely contribute to the remaining 34.5% of the variance.

Based on the findings, several key recommendations for future design improvements can be drawn. First, given the high impact of learnability on user experience, future iterations should focus on further simplifying the user interface. This could include clearer navigation, better labeling, and interactive tutorials to assist users in understanding the system's features. Efficiency can be enhanced by optimizing the application's performance, such as improving search algorithms and minimizing response times. These improvements would enable users to complete tasks more quickly and with less frustration, particularly in a high-demand academic setting where time is often limited.

The application's effectiveness could be further improved by ensuring that all features are fully functional and aligned with user needs. For instance, it would be valuable to continue iterating on task flows to ensure that every feature, such as accessing final assignments or viewing announcements, works seamlessly and as expected. Finally, increasing user satisfaction can be achieved by adding more personalized features, such as customized book recommendations, and improving user support services, such as more intuitive help systems or live chat options. Enhancing the emotional experience of users through aesthetic improvements and user-centric design can contribute to a more satisfying interaction with the application.

While the results of this study provide valuable insights, there are several limitations that should be acknowledged. The sample size for both the Concurrent Think Aloud (CTA) and Post Study System Usability Questionnaire (PSSUQ) assessments was relatively small, with only 10 participants in each group. This limited the generalizability of the findings, and future studies should include larger and more diverse user groups to strengthen the external validity of the results. Additionally, the study was conducted in a controlled environment, which may not fully reflect the conditions under which the application would be used in a real-world setting. Expanding the testing environment and conducting longitudinal studies would provide more comprehensive data on the system's performance and user experience over time.

Furthermore, while usability metrics were found to be significant predictors of user experience, it is important to consider other factors, such as user motivation, external technical constraints, or cultural preferences, that may also influence user perceptions and system usage. Future work should aim to include these contextual factors in the design evaluation to create a more holistic understanding of the user experience.

This study successfully demonstrates the importance of iterative design in improving the usability of mobile library applications. Through a combination of usability testing, user feedback, and statistical analysis, significant improvements were made in the application's effectiveness, efficiency, learnability, and satisfaction. The results emphasize the need for continued refinement of the system, with a particular focus on enhancing learnability and efficiency. The insights gained from this study provide a foundation for developing user-centered digital library systems that can better meet the needs of diverse student populations, supporting their academic success and overall satisfaction.

3. CONCLUSION

This research provides an important contribution to the development of mobile-based digital library applications with a Human Centered Design (HCD) approach. Through the systematic integration of usability evaluation using the Post-Study System Usability Questionnaire (PSSUQ) and Concurrent Think Aloud (CTA) methods, this study proves that a comprehensive evaluation process can significantly improve design quality and user experience. The analysis results show improvements in every aspect of usability metrics, where effectiveness, efficiency, satisfaction, and learnability experienced significant improvements after design iterations based on user feedback. Multiple linear regression analysis conducted on the questionnaire data confirmed these findings, indicating that all usability metrics positively influenced user experience. The study highlights the importance of learnability as the strongest predictor of user experience, suggesting future app designs prioritize intuitive navigation and onboarding support.

Thus, this study not only produces an interactive and user-friendly digital library application but also contributes to the scientific study of measuring and improving the usability of digital applications in educational settings. Practically, mobile library apps in higher education should adopt iterative HCD cycles to ensure usability-driven

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improvements that directly benefit students and librarians. This aligns with broader HCD methodologies shown to enhance usability and user experience across domains such as health and education [26], suggesting that similar approaches can strengthen digital library applications. This study is limited to students at IT Del and used simulated tasks rather than real-life usage. Moreover, the study was limited to one institution and short-term evaluation; future work should include longitudinal tracking and multi-institutional comparisons. Further research should explore adaptive interfaces, cross-platform integration, and broader student demographics to validate generalizability.

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