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COMBINING THE USER-CENTERED DESIGN METHOD WITH REQUIREMENT ENGINEERING TO IMPROVE USABILITY IN WEB-BASED APPLICATION

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ABSTRACT

Usability is a crucial factor in ensuring the effectiveness and user satisfaction of digital systems, especially in high-stakes contexts such as e-Assessment. This study proposes an integrated approach that combines User-Centered Design (UCD) and Requirement Engineering (RE) to address UCD's limitations and improve the Usability of web-based applications, with a case study on an e-Assessment system. The research framework involves five independent variables—User Need, User Behavior, User Motivation, User Requirement, and Functional Requirement—hypothesized to influence Usability, which in turn affects the core usability dimensions of Learnability, Efficiency, Memorability, Error, and Satisfaction. The integrated method incorporates RE's structured processes—elicitation, analysis, specification, and validation—into UCD's iterative cycle. A prototype was developed and tested using quantitative methods, including path analysis and usability evaluation. The findings reveal that user behavior plays the most critical role in shaping Usability, while Usability itself positively impacts all core dimensions. This study contributes to the field by operationalizing the integration of UCD and RE into a comprehensive framework and validating its effectiveness in a web-based application. It demonstrates, through the e-Assessment case, how aligning structured requirements with user-centered practices can enhance the overall user experience.

Keywords: *User-Centered Design, Requirement Engineering, e-Assessment, Usability, System Usability Scale*

1. INTRODUCTION

The rapid advancement of information technology has significantly transformed various aspects of daily human activities. Multiple stakeholders have actively contributed to the development of digital technologies. These technologies play a critical role in enhancing business operations by promoting Efficiency, reliability, and sustainability [1].

One of the most widely adopted forms of digital technology is web-based applications. These applications offer numerous advantages, including broad accessibility unrestricted by time or location, as well as high Efficiency. Their ease of use has contributed to their growing popularity among enterprises [2]. This trend reinforces the high demand for digital technology and its essential role in supporting daily activities. Consequently, application technologies have experienced rapid growth, leading to the emergence of various sectors designed to streamline everyday tasks. A wide range of applications continues to evolve, including those in e-commerce, e-finance, e-learning, and e-assessment.

There are numerous methods used in the development of web-based applications, one of which is the User-Centered Design (UCD) approach. UCD emphasizes designing products based on a deep understanding of user needs, behaviors, and preferences, ensuring that the final Application is both functional and user-friendly. This method is widely adopted in modern software development due to its ability to enhance usability and user satisfaction [3].

One example of a web-based application developed using the User-Centered Design (UCD) approach is an e-assessment platform created by an IT consulting firm. This e-assessment Application serves the company's internal business needs by supporting employee skill development and performance evaluation. The primary objective of the platform is to encourage employees to continually improve their competencies, enabling them to remain competitive in a rapidly evolving job market. Additionally, the Application is utilized as part of the company's promotion and salary adjustment processes.

Unfortunately, the Application developed by the company using the User-Centered Design (UCD) approach demonstrated poor Usability. Users found the system confusing and difficult to navigate, with an unclear application flow and disorganized data structures. The system architecture lacked clarity, contributing to a fragmented user experience.

This issue stemmed from the exclusive use of the UCD approach, which primarily focuses on user needs and experiences. UCD alone was insufficient for capturing comprehensive system requirements, particularly those related to functional and architectural aspects of the Application. This limitation highlights a critical shortcoming of the UCD approach: its inability to fully address the technical and structural requirements of complex systems [4].

Based on the identified limitations of the UCD approach, which contributed to the low Usability of the e-assessment Application, a redesign was conducted to improve its Usability by integrating UCD with the Requirement Engineering (RE) methodology. Requirement Engineering plays a crucial role in the successful development of Information Systems and Technology (IST). It supports the systematic documentation of system requirements, ensuring that all necessary specifications are identified and addressed throughout the development process [5].

This study focuses on examining the impact of the combined User-Centered Design and Requirement Engineering methodologies on Usability and its dimensions, including Learnability, Efficiency, Memorability, error rate, and user satisfaction. The research aims to analyze the extent to which the integration of UCD and RE significantly influences the Usability of the e-assessment Application, as well as to validate the proposed hypotheses. Additionally, this study compares the usability scores between the newly integrated method and the original pure UCD approach using the System Usability Scale (SUS). The results of this comparison will help determine which method is more effective in enhancing the Usability of the e-assessment Application. They can be considered superior for future development efforts.

2. LITERATURE REVIEW

This research focuses on integrating User-Centered Design (UCD) and Requirements Engineering (RE) methodologies to enhance the Usability of an e-assessment application developed by an IT consulting company. The objective is to ensure that the Application provides a seamless and intuitive user experience, minimizing confusion and reducing the complexity users face during interaction. The outcome of this integration will be presented in the form of a prototype, which will be evaluated using the System Usability Scale (SUS) to measure its usability performance.

The following section reviews and synthesizes key theories and concepts from previous studies that form the theoretical foundation of this research. These prior works serve as the basis for the methodological approach and support the rationale for combining UCD and RE in the development process.

2.1 E-Assessment Application

E-assessment refers to the process of assessment facilitated by digital technologies, particularly computer-based applications, to support diagnostic, formative, or summative evaluations through data analysis. These assessments often incorporate insights derived from social, academic, and adaptive learning contexts [6].

As a web-based application, e-assessment enables assessments to be conducted online, offering users the flexibility to participate at any time and from anywhere, in accordance with scheduled sessions. This flexibility enhances accessibility and convenience for examinees. Furthermore, e-assessment systems are capable of storing responses and evaluation data while supporting various perspectives within the assessment process, including those of learners or assessees, educators or assessors, educational institutions, accreditation bodies, regulatory authorities, and the general public [6].

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2.2 User-Centered Design

User-Centered Design (UCD) is a design approach that prioritizes users as the central focus of the development process. It emphasizes the importance of understanding users' needs, preferences, and experiences to create products that are accessible, usable, and satisfying. [7].

UCD involves active user participation throughout the entire design lifecycle—from planning and requirements gathering to prototyping and evaluation. By incorporating continuous user feedback and iterative refinement, UCD ensures that the resulting product aligns closely with user expectations and usage contexts. This approach ensures that digital systems are not only functional but also intuitive and user-friendly within the environments in which they are deployed [8]. The User-Centered Design (UCD) process is typically divided into four main phases:

Understand and Specify the Context of Use: This phase focuses on identifying the users and stakeholders who interact with the system, as well as their roles and responsibilities. Users are categorized based on relevant characteristics such as age, gender, educational background, and experience level. The goal is to gain a comprehensive understanding of the environment in which the system will be used.

Specify User Requirements: In this phase, data related to user needs is collected and analyzed. These needs are then translated into specific requirements using various formats such as user stories, scenarios, diagrams, or visual models. This ensures that the design is grounded in actual user expectations and usage patterns.

Producing Design Solutions: Based on the user requirements, initial design concepts are developed. These may include sketches, wireframes, mockups, or interactive prototypes. The design solutions aim to reflect the identified needs and provide a basis for user validation.

Evaluating the Designs: The final phase involves assessing the proposed design solutions to determine their effectiveness and alignment with user needs. This may include usability testing and heuristic evaluation to ensure the design adheres to usability principles and provides a satisfactory user experience.

2.3 Requirement Engineering

Requirement Engineering (RE) is a critical phase within the Software Development Life Cycle (SDLC). It involves a systematic process for identifying, analyzing, documenting, and validating the needs and expectations of stakeholders, which subsequently serve as the foundation for system development [9].

Requirements Engineering is generally divided into two main components: Requirements Development and Requirements Management. Requirement Development focuses on the elicitation, analysis, specification, and validation of requirements [10].

Elicitation: The primary activity is to gather information from relevant stakeholders. This process aims to identify existing problems, define system boundaries, and capture initial expectations. Elicitation in requirements engineering focuses on two main aspects: the problem domain, which refers to the issues that the software aims to address, and the user domain, involving stakeholders who are influenced by or affected by the system.

Analysis: Requirement analysis involves reviewing and interpreting the data obtained during elicitation to detect inconsistencies, conflicts, and missing information. This stage refines general user needs into specific, structured requirements and often includes the development of analysis models. The goal is to produce accurate, complete, and verifiable requirements to guide the design, development, and testing processes.

Specification: The specification phase documents the identified requirements in a clear and organized manner, accessible to both technical and non-technical stakeholders. Based on the outcomes of elicitation and analysis, this phase formalizes functional and non-functional requirements into a Software Requirements Specification (SRS) document, which serves as a reference throughout the system development lifecycle.

Validation: Validation ensures that the documented requirements align with stakeholder expectations and system goals. This phase verifies the correctness, completeness, and feasibility of the requirements through activities such as Usability Testing (UT) and User Acceptance Testing (UAT). The purpose is to confirm that the system, when built, will meet the desired quality standards and user needs.

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2.4 Usability

Usability is defined as the extent to which specified users can use a product to achieve specified goals with effectiveness, Efficiency, and Satisfaction in a specified context of use. It serves as a measure of how well users can interact with a system to complete tasks successfully, with minimal effort, and with a positive experience in a particular usage environment [11].

In principle, an application is considered to have a good level of Usability if users can operate it with ease and the Application can fulfill the intended functions or objectives as expected by the user [12]. Usability is often evaluated based on five key dimensions:

Learnability refers to the ease with which users can learn and use a system. A usable system should allow users to quickly understand how to operate it and begin working without extensive training or prior experience.
Efficiency: Once users have learned the system, it should enable them to perform tasks effectively and reach high levels of productivity with minimal wasted effort or time.
Memorability: A well-designed system should be easy to remember. Users who return to the system after a period of inactivity should be able to reestablish proficiency without having to relearn everything from scratch.
Errors: The system should minimize the occurrence of user errors. Furthermore, when mistakes do occur, they should be easy to detect, understand, and recover from, without causing significant disruption or confusion.
Satisfaction: The system should provide a pleasant and satisfying user experience, fostering user confidence and acceptance through comfort, aesthetics, and responsiveness.

2.5 System Usability Scale

The System Usability Scale (SUS) is a widely used method for evaluating Usability, consisting of a ten-item questionnaire that utilizes a Likert scale to assess users' subjective perceptions of system usability [13].

Initially introduced by John Brooke in 1986, the SUS was designed to offer a quick and reliable tool for evaluating the Usability of a wide range of systems and products. Each of the ten items contributes to a composite score that reflects the overall Usability of the system [14].

As stated in [15], the System Usability Scale (SUS) scoring rules are as follows:

- For odd-numbered items (positive statements): Score = Respondent's score – 1
- For even-numbered items (negative statements): Score = 5 – Respondent's score

After adjusting all ten responses using these rules, the total raw score is obtained by summing the individual item scores. This raw score is then multiplied by 2.5 to convert it into a final SUS score that ranges from 0 to 100. A higher score indicates better perceived Usability.

Table 1 : SUS Score

SUS Score Range	Usability Rating
> 80.3	Excellent (A)
68 – 80.3	Good (B)
68	Okay (C)
51- 68	Poor (D)
< 51	Awful (E)

2.6 Related Work

Research on addressing the limitations of User-Centered Design (UCD) has been widely conducted, particularly through its integration with Requirement Engineering (RE). Most studies emphasize the importance of user involvement in system design; however, the integration of UCD and RE remains incomplete, leaving several research gaps. The following studies are considered relevant references and serve as the foundation for the present research.

Based on Aulia research [16], this issue was addressed by combining UCD and RE in the development of a web-based e-learning application. Usability testing using the System Usability Scale (SUS) showed improvement, with a score of 75.54. However, the study mainly focused on usability outcomes, leaving the role of RE variables in enhancing UCD effectiveness underexplored. Similarly, Xiao et al. proposed a User-Centered Requirement framework that classified requirements into Usability, workflow, and UI requirements. This approach was claimed to improve validation, flexibility, and Efficiency in software development [17]. Nevertheless, the study presented only a conceptual framework without detailing its practical implementation in real-world applications, making the steps and procedures unclear.

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Additionally, the variables used in this study are adapted from previous studies. User Needs, User Behavior, and User Motivation are central components of UCD [18]. From the perspective of Requirement Engineering, both User Requirements and Functional Requirements have been emphasized as critical elements in developing flexible and efficient systems [17]. Usability, as discussed by Josephine et al. , is widely assessed through five dimensions: Learnability, Efficiency, Memorability, Error, and Satisfaction [19].

Based on these findings, this research incorporates six key variables: User Needs, User Behavior, User Motivation, User Requirements, Functional Requirements, and Usability (with its five dimensions). However, despite previous attempts to integrate UCD and RE, prior studies have not proposed a comprehensive model nor empirically tested it within real-world contexts. Therefore, this study develops an integrative UCD–RE conceptual framework and validates it empirically in the context of web-based software development, particularly for e-assessment applications, to investigate its impact on usability and learning achievement.

3. RESEARCH METHODOLOGY

This study adopts a quantitative approach to empirically examine the integration of User-Centered Design (UCD) and Requirement Engineering (RE) in the development of a web-based application (e-Assessment Application). The methodology is designed to ensure that the research objectives—improving system usability and its impact on learning achievement—can be systematically tested and validated. The evaluation is conducted using the System Usability Scale (SUS) on the prototype developed from the integrated approach and compared with the previous version developed using the original UCD.

3.1 Research Design

This study employs a quantitative explanatory research design. Data were collected through surveys using structured questionnaires, complemented by a focus group discussion to support the evaluation process. The study compared two contexts: (1) the existing Application developed solely with UCD, and (2) a prototype redesigned using a combined UCD–RE approach.

The constructs of this study were adapted from prior literature. From the UCD perspective, User Needs, User Behavior, and User Motivation were adopted as key variables [18]. From the RE perspective, User Requirements and Functional Requirements were included as critical elements [17]. Finally, Usability was measured through five dimensions: Learnability, Efficiency, Memorability, Errors, and Satisfaction [19].

Data analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS 4. This technique was chosen for its suitability in analyzing complex models with multiple latent variables and relatively small sample sizes. The findings were used to test the hypotheses and evaluate whether the proposed integrative framework significantly improves Usability on a web-based Application.

3.2 Conceptual Framework

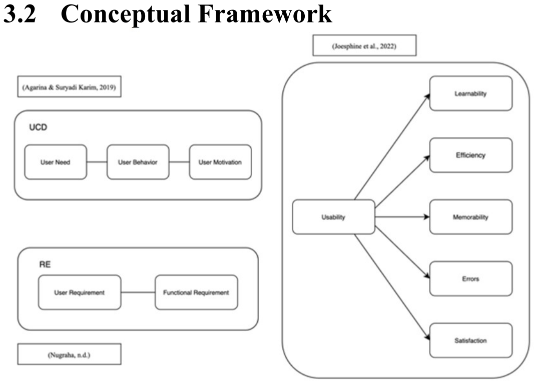

Figure 1 Conceptual Models

Synthesizing constructs developed the conceptual framework from UCD and RE. As illustrated in Figure 1 (Variable Development Process), independent variables were drawn from UCD—User Needs, User Behavior, and User Motivation—and from RE—Functional Requirements and User Requirements. These variables capture both user-centered and requirement-driven aspects of software design.

The dependent construct, Usability, was operationalized using five measurable dimensions: Learnability, Efficiency, Memorability, Errors, and Satisfaction. In addition, Learning Achievement was introduced as the ultimate dependent variable, reflecting the contribution of system usability to educational outcomes.

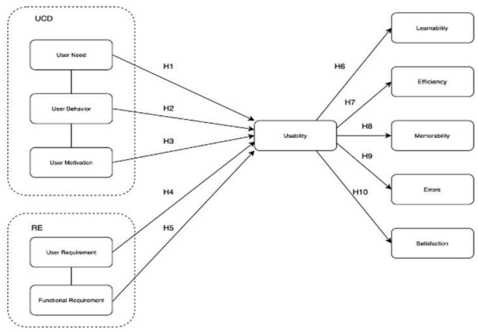

Figure 2 Research Model

The integration of these variables into the final conceptual framework is presented in Figure 2 (Research Model), which illustrates the hypothesized relationships: UCD and RE variables influence Usability, which in turn influences learning achievement.

3.3 Hypotheses

Based on the Conceptual Framework, testable hypotheses were formulated to validate the proposed model empirically. The variables used in this research are derived from the integration of User-Centered Design (UCD) and Requirement Engineering (RE) methods. Usability serves as the dependent variable, which is further measured through five dimensions: Learnability, Efficiency, Memorability, Errors, and Satisfaction. These dimensions are assessed using the System Usability Scale (SUS) questionnaire. Based on these variables and the applied methods, the research hypotheses are formulated to analyze the significant impact of UCD and RE variables on the overall Usability of the e-assessment Application.

H1 USER NEEDS AFFECT THE USABILITY VALUE OF THE E-ASSESSMENT APPLICATION

H_0: There is no significant effect of User Needs on Usability in the e-Assessment Application.
H_1: There is a significant influence of User Needs on increasing Usability in the e-Assessment Application.

H2 USER BEHAVIOR AFFECTS THE USABILITY VALUE OF THE E-ASSESSMENT APPLICATION

H_0: There is no significant effect of User Behavior on Usability in the e-Assessment Application.
H_1: There is a significant influence of User Behavior on Usability in the e-Assessment Application.

H3 USER MOTIVATION AFFECTS THE USABILITY VALUE OF THE E-ASSESSMENT APPLICATION

H_0: There is no significant effect of User Motivation on Usability in the e-Assessment Application.
H_1: There is a significant influence of User Motivation on Usability in the e-Assessment Application.

H4 USER REQUIREMENT AFFECTS THE USABILITY VALUE OF THE E-ASSESSMENT APPLICATION

H_0: There is no significant effect of User Requirement on Usability in the e-Assessment Application.
H_1: There is a significant influence of User Requirement on Usability in the e-Assessment Application.

H5 FUNCTIONAL REQUIREMENT AFFECTS THE USABILITY VALUE OF THE E-ASSESSMENT APPLICATION

H_0: There is no significant effect of Functional Requirement on Usability in the e-Assessment Application.
H_1: There is a significant influence of Functional Requirement on Usability in the e-Assessment Application.

H6 USABILITY OF THE E-ASSESSMENT APPLICATION FORMED BY THE INDEPENDENT VARIABLES AFFECTS LEARNABILITY.

H_0: Usability formed from the proposed method has no significant effect on Learnability or ease of understanding the Application.
H_1: Usability formed from the proposed method has a significant effect on Learnability, or ease of understanding the Application.

H7 USABILITY OF THE E-ASSESSMENT APPLICATION FORMED BY THE INDEPENDENT VARIABLES AFFECTS EFFICIENCY.

H_0: Usability formed from the proposed method has no significant effect on Efficiency or the user's ability to understand features and complete work quickly.
H_1: Usability formed from the proposed method has a significant effect on Efficiency or the user's ability to understand features and complete work quickly.

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H8 USABILITY OF E-ASSESSMENT APPLICATIONS FORMED BY THE INDEPENDENT VARIABLES AFFECTS MEMORABILITY.

H_0: Usability formed from the proposed method has no significant effect on Memorability or the user's ability to remember how to use the Application.

H_1: Usability formed from the proposed method has a significant effect on Memorability, or the user's ability to remember how to use the Application.

H9 USABILITY OF THE E-ASSESSMENT APPLICATION FORMED BY THE INDEPENDENT VARIABLES AFFECTS THE ERROR RATE.

H_0: Usability formed from the proposed method has no significant effect on the level of errors or the number of errors that occur in using the Application.

H_1: Usability formed from the proposed method has a significant effect on the level of errors or the number of errors that occur in using the Application.

H10 USABILITY OF THE E-ASSESSMENT APPLICATION FORMED BY THE INDEPENDENT VARIABLES AFFECTS SATISFACTION.

H_0: Usability formed from the proposed method has no significant effect on Satisfaction or the level of user satisfaction with the experience of using the Application.

H_1: Usability formed from the proposed method has a significant effect on Satisfaction or the level of user satisfaction with the experience of using the Application.

3.4 Sample of Data Collection

The data were collected from users of an e-Assessment application at an IT consulting company. The data collection involved distributing surveys regarding the use of the Application, which was designed by combining User-Centered Design and Requirement Engineering methods. The total population of users involved in this study is approximately 111 respondents.

Therefore, the entire population of users of the e-Assessment Application will serve as the sample for this research. By using the whole population as the sample, the testing can be more precise and yield data that is more representative and relevant.

3.5 Method of Data Analysis

In this study, data analysis was conducted using SmartPLS 4 software. The analysis process consists of two main stages: the measurement model (validity and reliability testing) and the structural model (path analysis).

After the questionnaires were distributed, the collected respondent data were compiled and organized in Microsoft Excel to facilitate further processing in SmartPLS. The SmartPLS tool was then used to perform model testing, aiming to analyze the relationships among variables and to verify whether the proposed hypotheses are accepted or rejected.

3.5.1 Measurement Model

The measurement model aims to measure and ensure that the questionnaire instruments are both valid and reliable. This phase includes two main types of testing: the Validity Test and the Reliability Test.

Validity: refers to the degree to which an instrument accurately measures what it is intended to measure. An instrument is considered valid if it precisely captures the concept being studied [20].

Reliability: measures the consistency of the results produced by the research instrument. A reliable instrument will yield consistent outcomes across repeated measurements [20].

Table 2 Rule of Thumb for Testing Measurement Model

Type Test	Parameter	Rule of Thumb	References
Convergent Validity	Outer Loading	> 0.70	(Manley et al., 2021)
	Average Variance Extracted	≥ 0.50	(Manley et al., 2021)
Reliability	Cronbach's Alpha	> 0.70	(Manley et al., 2021)
	Composite Reliability	> 0.70	(Manley et al., 2021)

3.5.2 Structural Model

The primary objective of structural model testing is to analyze the relationship between exogenous and endogenous latent variables. To evaluate the structural model, several key indicators are utilized, including:

a. Coefficient of Determination (R^2)

This metric represents the proportion of variance in the dependent variable that the independent variables can explain. R^2 remains consistent across linear transformations and provides reliable forecasting when its value approaches one, regardless of the scale used to measure the variables [5].

b. Path Coefficients

Path coefficients illustrate the nature and strength of the relationships between variables, indicating whether the effect is positive or negative. These values are standardized and fall within the range of -1 to +1.

c. T-Statistics

T-statistics are calculated using the bootstrapping method to assess the statistical significance of the relationships between latent variables. This value helps determine whether the data support the hypothesized paths in the model.

Table 3 Rule of Thumb for Structural Model

Parameter	Rule of Thumb	References
Coefficient of Determination (R^2)	The R^2 value indicates the strength of the predictive accuracy of the model and is classified as follows : ≥0.67: Substantial (strong) ≥0.33: Moderate ≥ 0.19: Weak	(Manley et al., 2021)
Path Coefficients	A value close to +1 indicates a strong positive relationship, while a value close to -1 indicates a negative relationship. A path coefficient is generally considered statistically significant if the value is greater than or equal to 0.05	(Manley et al., 2021)
T-Statistics	The relationship between latent variables is considered significant when the T-statistic > 1.96 at a 5% significance level (two-tailed). If the T-statistic is less than 1.96, the relationship is considered not statistically significant.	(Manley et al., 2021)

4. RESULT AND DISCUSSION

This section will present the results and discussion of the research.

4.1 Respondent Profiles

The distributed questionnaire included general respondent information such as name, gender, organization, and job position. All participants had prior experience using the Exam Room prototype through a provided trial link, ensuring they had direct interaction with the Application.

Table 4 Distribution of Respondents by Gender

Profile	Category	Number of Respondents	Percentage (%)
Gender	Male	44	39.6
	Female	67	60.4
Total		111	100

According to Table 4, the number of female respondents exceeded that of male respondents. Female respondents accounted for 67 individuals (60.4%), while male respondents totaled 44 individuals (39.6%).

Table 5 Distribution of Respondents by Company

Profile	Category	Number of Respondents	Percentage (%)
Company	Techno Infinity	40	36
	Proxsis Group	31	27.9
	SAI Assessment	24	21.6
	BP Tapera	16	14.4
Total		111	100

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Refer to Table 5, which shows the distribution of respondents by company or institution. The majority of respondents came from Techno Infinity, totaling 40 respondents (36%). This was followed by Proxsis Group, with 31 respondents (27.9%), SAI Assessment (Proxsis HR), with 24 respondents (21.6%), and BP Tapera, with 16 respondents (14.4%).

Table 6 Distribution of Respondents by Job Position

Profile	Category	Number of Respondents	Percentage (%)
Job Position	Staff	64	57.7
	Consultant	23	20.7
	Assessor	14	12.6
	Developers	10	9
Total		111	100

The distribution of respondents by job position indicates that most of them held staff positions, with 64 individuals (57.7%) holding such positions. This was followed by consultants (23 respondents, 20.7%), assessors (14 respondents, 12.6%), and developers (10 respondents, 9%).

4.2 Analysis Models

Before the data are processed and analyzed, a path model is constructed to represent the structure of the proposed research model visually. The model is developed based on the integration of User-Centered Design and Requirements Engineering methods, and usability evaluation is conducted using the System Usability Scale (SUS).

Path analysis was conducted to examine the influence of the independent variables (User Need, User Behavior, User Motivation, User Requirement, and Functional Requirement) on the dependent variables (Usability, Learnability, Efficiency, Memorability, Error, and Satisfaction).

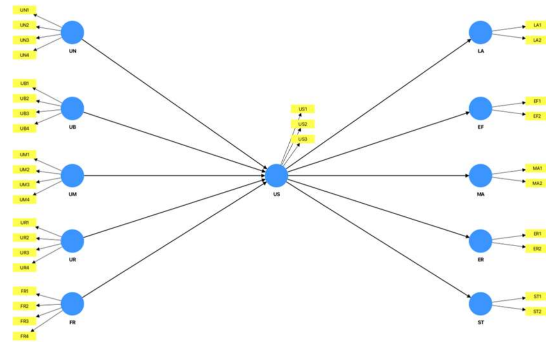

Figure 3 Analysis Models

In this analysis, several statistical tests were employed to evaluate the quality and significance of the relationships between variables. The analysis of the process includes Measurement Model Testing and Structural Model Testing.

4.2.1 Measurement Model Testing

The measurement model test is conducted to ensure that the indicators used are both valid and reliable. Convergent validity is assessed through outer loading and Average Variance Extracted (AVE), while reliability is evaluated using Cronbach's Alpha and Composite Reliability (CR). These tests confirm that the constructs consistently measure the intended variables.

a. Convergent Validity Test

Convergent validity was assessed to ensure that each questionnaire indicator accurately represented its intended construct. Two key metrics were used: outer loading and Average Variance Extracted (AVE), analyzed using SmartPLS 4. Indicators were considered valid if they met the thresholds: outer loading > 0.70 and AVE ≥ 0.50.

Table 7 Value Outer Loading

Indicator	Outer Loading
UN1	0.856
UN2	0.841
UN3	0.850
UN4	0.796
UB1	0.804
UB2	0.853
UB3	0.840
UB4	0.822
UM1	0.811
UM2	0.821
UM3	0.840
UM4	0.783
UR1	0.771
UR2	0.853
UR3	0.817

UR4	0.783
FR1	0.868
FR2	0.869
FR3	0.832
FR4	0.862
US1	0.846
US2	0.809
US3	0.827
LA1	0.902
LA2	0.850
EF1	0.898
EF2	0.885
MA1	0.876
MA2	0.887
ER1	0.908
ER2	0.868
ST1	0.814
ST2	0.937

(Data Source: SmartPLS output)

Table 8 Value Average Variance Extracted (AVE)

Variable	AVE
UN	0.699
UB	0.688
UM	0.662
US	0.650
FR	0.736
US	0.685
LA	0.768
EF	0.795
MA	0.777
ER	0.789
ST	0.770

(Data Source: SmartPLS output)

Based on the validity test results presented above, all indicators met the required thresholds. The outer loading values ranged from 0.771 to 0.937, exceeding the minimum threshold of 0.70, indicating that all indicators were valid. In addition, the AVE values ranged from 0.650 to 0.795, also surpassing the required minimum of 0.50. Therefore, the constructs in this study demonstrate good convergent validity.

b. Reliability Test

Reliability testing was conducted using two key parameters: Cronbach's Alpha and Composite Reliability, both of which assess the internal consistency of the constructs. A construct is considered reliable if both values exceed 0.70.

Table 9 Cronbach's Alpha Value and Composite Reliability Value

Variabel	Cronbach's Alpha	Composite Reliability
UN	0.856	0.903
UB	0.850	0.898
UM	0.830	0.887
US	0.823	0.881
FR	0.882	0.918
US	0.771	0.867
LA	0.701	0.869
EF	0.742	0.886
MA	0.714	0.875
ER	0.734	0.882
ST	0.717	0.870

(Data Source: SmartPLS output)

Refer to Table 9, Cronbach's Alpha values ranged from 0.701 to 0.882, while Composite Reliability values ranged from 0.867 to 0.918. All values meet the required thresholds, indicating that all constructs in this study demonstrate good reliability.

4.2.2 Structural Model Testing

a. Coefficient of Determination (R^2)

The Coefficient of Determination (R^2) is used to assess the combined influence of exogenous variables on an endogenous variable. R^2 values are categorized as follows:

1). $R^2 \geq 0.67$ = Strong
2). $R^2 \geq 0.33$ = Medium
3). $R^2 \geq 0.19$ = Weak

Table 10 Value Coefficient of Determination (R^2)

Variable Endogen	R-Square	Annotation
US	0.389	Medium

(Data Source: SmartPLS output)

Based on the results presented in Table 10, the R^2 value for the Usability (US) construct is 0.389. This indicates that the independent variables—User Need (UN), User Behavior (UB), User Motivation (UM), User Requirement (UR), and Functional Requirement (FR)—collectively explain 38.9% of the variance in Usability. The remaining 61.1% is attributed to other factors not included in this research model.

b. Path Coefficients

The path coefficient indicates the direction and strength of the relationship between constructs. Its value ranges from -1 to +1, where a value closer to +1 signifies a strong positive

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relationship, and a value closer to -1 indicates a strong negative relationship. Values approaching zero suggest a weaker relationship between variables.

Table 11 Value Path Coefficients

Line Relationship	Original Sample (O)	Relationship
UN -> US	0.167	Positive
UB -> US	0.268	Positive
UM -> US	0.145	Positive
UR -> US	0.052	Positive
FR -> US	0.145	Positive
US -> LA	0.542	Positive
US -> EF	0.368	Positive
US -> MA	0.394	Positive
US -> ER	0.507	Positive
US -> ST	0.290	Positive

(Data Source: SmartPLS output)

Table 11 presents the path coefficient values ranging from 0.052 to 0.542, all indicating a positive direction. This suggests that each exogenous variable in the model has a positive influence on the endogenous variables. Specifically, User Need (UN), User Behavior (UB), User Motivation (UM), User Requirement (UR), and Functional Requirement (FR) have positive effects on Usability. Subsequently, Usability also exerts a positive influence on Learnability (LA), Efficiency (EF), Memorability (MA), Errors (ER), and Satisfaction (ST). These results indicate that the relationships among variables in this research model are well-aligned and supportive.

c. T-Statistics

The t-statistic is used to test the significance of the relationship between variables. In this study, the threshold value for statistical significance is set at 1.96, corresponding to a 5% significance level ($\alpha = 0.05$). This means that if the T-statistic value is greater than or equal to 1.96, the relationship is considered statistically significant. Conversely, if the T-statistic value is less than 1.96, the relationship is considered not statistically significant.

Table 12 Value T-Statistics

Line Relationship	T-Statistics (|O/STDEV|)	Annotation
UN -> US	1.030	No Significant
UB -> US	2.066	Significant
UM -> US	1.190	No Significant
UR -> US	1.363	No Significant
FR -> US	0.488	No Significant
US -> LA	3.454	Significant
US -> EF	5.919	Significant
US -> MA	6.732	Significant
US -> ER	3.989	Significant
US -> ST	3.473	Significant

(Data Source: SmartPLS output)

Refer to Table 12, five path relationships were found to be statistically insignificant, as their T-statistic values were below the threshold of 1.96. These include the relationships from UN to US, UM to US, UR to US, and FR to US. In contrast, six other paths demonstrated statistical significance with T-statistics greater than 1.96, including UB → US, US → LA, US → EF, US → MA, US → ER, and US → ST. These findings suggest that not all positively directed relationships (as indicated by the path coefficients) are statistically significant.

4.3 Hypotheses Test

Hypothesis testing aims to assess the significance of relationships between exogenous variables (User Need, User Behavior, User Motivation, User Requirement, Functional Requirement) and endogenous variables (Usability, Learnability, Efficiency, Memorability, Error, Satisfaction). The evaluation is based on the T-statistic value, where a value of ≥ 1.96 indicates a significant effect (H_1 accepted), while a value of < 1.96 indicates a non-significant effect (H_0 accepted). Although path coefficients show the direction of influence, significance is determined through T-statistic results. The findings show that not all positively correlated paths are statistically significant, emphasizing the importance of hypothesis testing in model validation.

Table 13 Hypothesis Test Result

Hypothesis	Line Relationship	T-Statistics (|O/STDEV|)	Conclusion
H1	UN -> US	1.030	Not Significant, H0 is accepted
H2	UB -> US	2.066	Significant, H1 is Accepted
H3	UM -> US	1.190	Not Significant, H0 is accepted

H4	UR -> US	1.363	Not Significant, H0 is accepted
H5	FR -> US	0.488	Not Significant, H0 is accepted
H6	US -> LA	3.454	Significant, H1 is Accepted
H7	US -> EF	5.919	Significant, H1 is Accepted t
H8	US -> MA	6.732	Significant, H1 is Accepted
H9	US -> ER	3.989	Significant, H1 is Accepted
H10	US -> ST	3.473	Significant, H1 is Accepted

Based on the hypothesis testing results presented in Table 13, the following conclusions can be drawn:

H_1: User Need has a significant effect on Usability in the e-Assessment Application.
The T-statistic value for the path UN → US is 1.030, which is below the threshold of 1.96. This means that H_0 is accepted and H_1 is rejected, indicating that User Need does not have a significant effect on Usability in the e-Assessment Application.

H_2: User Behavior has a significant effect on Usability in the e-assessment Application.
The T-statistic value for the path UB → US is 2.066, which is above 1.96. This result implies that H_0 is rejected and H_1 is accepted, confirming that User Behavior has a significant effect on Usability in the e-Assessment Application.

H_3: User Motivation has a significant effect on Usability in the e-assessment Application.
The T-statistic value for the path UM → US is 1.190, which is below 1.96. This means that H_0 is accepted and H_1 is rejected, indicating that User Motivation does not significantly affect Usability in the e-Assessment Application.

H_4: User Requirement has a significant effect on Usability in the e-Assessment Application.
The T-statistic value for the path UR → US is 1.363, which is below 1.96. Therefore, H_0 is accepted and H_1 is rejected, which means that the User Requirement does not significantly influence Usability.

H_5: Functional Requirement has a significant effect on Usability in the e-Assessment Application.
The T-statistic value for the path FR → US is 0.488, which is below 1.96. This indicates that H_0 is accepted and H_1 is rejected, demonstrating that Functional Requirement has no significant effect on Usability in the e-Assessment Application.

H_6: Usability significantly affects Learnability in the e-Assessment Application.
The T-statistic value for the path US → LA is 3.454, which is above 1.96. Therefore, H_0 is rejected and H_1 is accepted, indicating that Usability, as formed through the proposed method, has a significant effect on Learnability or users' ease in understanding how to use the Application.

H_7: Usability significantly affects Efficiency in the e-Assessment Application.
The T-statistic value for the path US → EF is 5.919, which is above 1.96. This implies that H_0 is rejected and H_1 is accepted, confirming that Usability significantly impacts Efficiency, particularly in users' ability to understand features and complete tasks quickly.

H_8: Usability significantly affects Memorability in the e-Assessment Application.
The T-statistic value for the path US → MA is 6.732, which exceeds 1.96. Hence, H_0 is rejected and H_1 is accepted, meaning Usability has a significant impact on Memorability, or the users' ability to remember how to operate the Application.

H_9: Usability significantly affects Errors in the e-Assessment Application.
The T-statistic value for the path US → ER is 3.989, which is above 1.96. This leads to the rejection of H_0 and acceptance of H_1, indicating that Usability significantly influences the number of Errors, the frequency of user mistakes while operating the Application.

H_{10}: Usability significantly affects Satisfaction in the e-Assessment Application.
The T-statistic value for the path US → ST is 3.473, which is above the 1.96 threshold. This

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means that H_0 is rejected and H_1 is accepted, indicating that Usability has a significant effect on Satisfaction, particularly in terms of users' Satisfaction with the application experience.

4.4 Comparing Usability: Proposed Method & UCD

After completing the data analysis process in the previous chapter, the following chapter focuses on the System Usability Scale (SUS) scores. The data presented here were obtained, processed, and analyzed based on the implementation of the proposed method, which integrates User-Centered Design (UCD) and Requirement Engineering (RE). The outcome of this research is a prototype application that 111 e-assessment users have tested.

In this chapter, the SUS scores will be calculated for both the prototype developed using the proposed method and the e-assessment Application built with the original UCD method. However, since the dataset from the pure UCD method consists of only 78 respondents, a random sample of 78 users will also be selected from the proposed method group to ensure a fair comparison. The following sections present the SUS score calculations based on these samples:

a. SUS Calculation Proposed Method

We calculate the average value of the questionnaire responses using the following formula:

$$\overline{x} = \frac{\sum x}{\eta} = \frac{2133}{78} = 27.34 \qquad (1)$$

The resulting average score is 27.34. To obtain the final SUS score, this average value is multiplied by 2.5 according to the standard SUS scoring method:

$$SUS = \overline{x} \text{ x } 2,5$$

$$SUS = 27.34 \text{ x } 2.5 = 68.3$$

Thus, the SUS score for the proposed method is 68.3, which falls under Grade B, indicating a usability level categorized as "Good" or "Acceptable."

b. SUS Calculation Original User-Centered Design Method

We calculate the average value of the questionnaire responses using the following formula:

$$\overline{x} = \frac{\sum x}{\eta} = \frac{1739}{78} = 22.29 \qquad (2)$$

The resulting average score is 22.29. To obtain the final SUS score, this average value is multiplied by 2.5 according to the standard SUS scoring method:

$$SUS = \overline{x} \text{ x } 2,5$$

$$SUS = 22.29 \text{ x } 2.5 = 55.7$$

Therefore, the SUS score for the pure UCD method is 55.7, which falls into Grade D, indicating a usability level categorized as "Poor."

Based on the above calculations, there is a 12.6-point gap in SUS scores between the proposed method and the pure UCD method. This gap indicates that the integration of User-Centered Design and Requirement Engineering in the proposed approach results in an application with significantly improved Usability and better acceptance by users.

4.5 Discussion

The hypothesis testing results indicate that the proposed method—integrating User-Centered Design (UCD) and Requirement Engineering (RE)—significantly influences Usability, particularly through User Behavior. At the same time, other variables showed no significant effect. This highlights the critical role of actual user interaction patterns in system development.

Usability was quantitatively measured using the System Usability Scale (SUS). The prototype developed with the proposed method scored 68.3 (Grade B), indicating "Good" or "Acceptable" Usability. In contrast, the Application developed using pure UCD scored 55.7 (Grade D), categorized as "Poor." The 12.6 point difference demonstrates that combining UCD with RE yields a more usable application.

Furthermore, Usability positively impacted all core dimensions—Learnability, Efficiency, Memorability, Error, and Satisfaction—confirming the effectiveness of the integrated approach in enhancing user experience.

These findings validate the integration of RE's structured requirements process with UCD's iterative, user-focused design as an effective strategy to improve digital assessment systems. Future improvements could focus on better aligning requirement elicitation with observed user behavior through enhanced feedback mechanisms.

In summary, the proposed method enhances Usability by bridging the gap between system requirements and user experience, as supported by both statistical analysis and SUS scores.

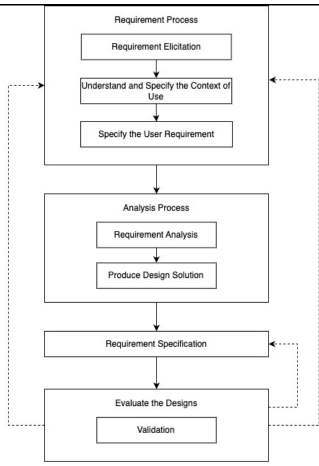

Figure 4 proposes the stages of the UCD and RE method.

Beyond statistical testing, this study also makes methodological contributions by outlining the integration process of UCD and RE. As illustrated in Figure X (Proposed Method), the proposed method incorporates the key stages of RE—Elicitation, Analysis, Specification, and Validation—into UCD's iterative, user-focused design. This integration was intended to address limitations of UCD by ensuring that user requirements were systematically captured, analyzed, and validated before design evaluation.

By presenting both the methodological framework and its empirical validation, this research extends prior works [16], [17]. which either remained conceptual or focused solely on usability testing without explaining the integration stages. The findings validate the integration of RE's structured requirements process with UCD's user-centered design as an effective strategy to improve web-based assessment systems.

5. SUGGESTION

This study acknowledges certain limitations that may serve as a reference for further research and development. Therefore, the following suggestions are proposed to help improve future studies and support the effective implementation of the combined User-Centered Design (UCD) and Requirement Engineering (RE) methods:

1. The proposed method can be applied to other types of applications beyond e-Assessment. This aims to explore its contribution to enhancing the quality of different systems and assessing its effectiveness in identifying user needs and analyzing system requirements in a more structured manner.
2. Future validation processes are encouraged to involve a broader range of respondents or users. A larger and more diverse sample can yield more representative and effective results that better reflect the overall needs of the user population.
3. In addition to the System Usability Scale (SUS), future research may consider incorporating alternative usability evaluation approaches, such as Heuristic Evaluation or other usability assessment methods, to gain more comprehensive and well-rounded insights.

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