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OPTIMIZING THE USER INTERFACE DESIGN OF WASTE BANK APPLICATION USING UCD AND UEQ

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Abstract

Environmental cleanliness is an essential aspect of life to make a healthy and comfortable environment. In Indonesia, the volume of waste will reach 70 million tons by 2022, with around 24% or 16 million tons needing to be appropriately managed. Related to the significant waste growth, the Ministry of Environment has developed the Waste Bank initiative, a collaborative effort that aims to educate the public in sorting waste and raising awareness of the importance of wise waste management. The desire of the local environmental agency to connect with the community supports the researcher in developing the Waste Bank application. The application will implement an optimal User Interface (UI) and User Experience (UX) design. The User-Centered Design (UCD) method will be employed, supported by the User Experience Questionnaire (UEQ), and is used to design UI and UX for the Waste Bank mobile application. The application prototypes were tested and evaluated using UEQ. The first design achieved an average score but still required improvement. In contrast, the second design scored excellently in six aspects measured: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty, with significant improvement. These results show that the UCD and UEQ methods are effective for developing UI/UX designs to meet user needs and can be applied in mobile application developments.

Keywords : Mobile Application, UCD, UEQ, Waste Bank,

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INTRODUCTION

Environmental cleanliness is an essential aspect of life to create healthy and comfortable conditions. A dirty environment can significantly harm human health, while a clean environment will provide positive benefits [1]. Currently, the volume of waste in Indonesia has reached 68.5 million tons and will increase to 70 million tons by 2022 [2]. Of this amount, about 24% or about 16 million tons of waste must be appropriately managed. Based on this data, Indonesia ranks as the fifth largest waste-producing country in the world. The Ministry of Environment has developed the Waste Bank initiative to address the significant waste growth in Indonesia.

This social engineering program aims to educate the public about sorting waste and raise awareness of the importance of wise waste management. The importance of Waste Banks has increased with the issuance of Government of Household Waste and Similar Waste. This regulation requires producers to implement (3R) Reduce, Reuse, and Recycle activities [3], which is a crucial step in sustainable waste management efforts.

In addition, applying the 3Rs can shape the character of caring for the environment [4], [5]. Cleanliness also significantly impacts the economy of an innovative and environmentally conscious society [6]. As technology advances, innovations continue to develop to help people manage waste effectively [7], [8]. Widespread use of mobile phones among the public, with penetration reaching 65.87% in Indonesia [9], [10], shows that this device can be an effective and efficient tool in supporting waste management.

This condition encourages the development of a system that facilitates community connectivity with the Waste Bank through a Mobile application. This application is designed to simplify the process of sorting, collecting, and recycling waste and increase public awareness and participation in maintaining environmental cleanliness. Thus, technology not only accelerates the waste management process but also makes a positive contribution to the circular economy and environmental sustainability.

Currently, UI/UX design has made much progress, although there are still problems. One

problem often arises is the tendency to prioritize aesthetics over functionality, resulting in less-than-optimal navigation and user experience. In addition, using conventional design trends can lead to websites losing their unique identity, which in turn can cause user disinterest. Some visual designs also apply complicated steps to complete simple tasks, reducing user efficiency and comfort.

To enhance the development of the Waste Bank application, a well-crafted design is crucial for increasing public interest. Every website or mobile app should be equipped with an optimized User Interface (UI) and User Experience (UX) [11]. The UI, which refers to the visible, audible, or interactive parts of a system that users engage with to understand how it works [12], [13], [14], plays a significant role in user engagement. A well-designed UI is not just a visual element but a critical component that enhances the user's experience with the application [15].

A well-designed UI ensures the application efficiently fulfills user needs during interaction [16], [17]. According to the ISO 9241-210 standard, User Experience (UX) is an individual's perception and response when using a product, system, or service [18]. The quality of UX can influence whether users feel satisfied, comfortable, or motivated to continue using the system [19]. For this reason, UX should be crafted with specific techniques to provide the best possible experience for users [14], [20], [21]. A practical UX approach involves a deep understanding of user needs and preferences [22] and includes ongoing testing and refinement to enhance user comfort and satisfaction [23], [24].

This study develops the User Interface (UI) and User Experience (UX) for the Waste Bank mobile application by applying the User-Centered Design (UCD) method, complemented by the User Experience Questionnaire (UEQ). The UCD approach consists of five stages: planning the human-centered design, defining the context of use, specifying user and organizational requirements, creating design solutions, and evaluating the design based on user requirements [25], [26], [27]. This approach is practical as it focuses on user needs throughout the design process. Meanwhile, the UEQ serves as a tool to evaluate the overall user experience of a product [28]. This study uses UEQ to assess the app's UI/UX, as designed through the UCD method. The combination of UCD and UEQ provides higher service quality by focusing on factors that inspire user engagement and innovation with the product [29].

Previous studies have utilized the User-Centered Design (UCD) approach to evaluate User Interface (UI) and User Experience (UX) design, as demonstrated in research by Hasna Tania Yasmine and Wahyu Tisno, titled "UI/UX Design for Tourism Village Website Using the User-Centered Design Method" [29]. Their study analysed, designed, and compared website designs to enhance public interest in tourism. They redesigned the original website by employing the UCD method with a focus on web-based technology. Evaluation with the User Experience Questionnaire (UEQ) markedly improved the redesign.

The two researchers concluded that designing a website that suits user needs is crucial to increasing user interest. Mubiarto, Isnanto, and Windasari conducted another research entitled "User Interface and User Experience (UI/UX) Redesign on "BCA Mobile" Application Using User-centred Design (UCD) Method" [30]. This research aims to design UI/UX on the BCA Mobile application by responding to complaints defined through reviews on the Google Play Store so that the application can meet user needs. This research uses the user centered design method, which focuses on mobile-based technology. This research concludes that applying the User Centered Design method is essential in creating good design.

Based on the discussion and problems of the previous two studies, the User-centred Design (UCD) method and usability measurement using the User Experience Questionnaire (UEQ) can be used to evaluate UI/UX in an application. This method is advantageous in optimizing the user interface (UI) by enhancing user satisfaction, improving usability and efficiency, increasing engagement, and ensuring adaptability to diverse user needs. Therefore, this research aims to refine the approaches used previously. In addition to the UCD method, this research will use UEQ as a usability measurement step. Researchers will perform additional calculations to provide a more in-depth analysis, which has yet to exist in previous studies.

This research focuses on applying the User Centered Design (UCD) method as the first step in designing the Waste Bank application. The first step is to measure the User Experience Questionnaire (UEQ) of the UI/UX design that has been made before. Next, the design will be updated by considering the test results. After that, the updated design will be tested again, and the results will be compared with the data from the previous test. This method involves users actively so that the resulting design can fully match the

user's needs. This method ensures that the resulting product meets users' expectations, preferences, and needs by involving users in the design process. One of the keys to UI and UX is user needs and other factors such as expectations, attributes, and capabilities [31]. Therefore, in designing an optimal design, it is crucial to have a comprehensive understanding and consider various points of view [32]. Understanding users is essential to ensure they continue using the app.

Usability measurement using UEQ was chosen because UEQ makes it easy to measure user experience through a questionnaire containing questions to be answered by respondents [33], [34]. The UCD method and usability measurement with UEQ will produce applications that are more aligned with user needs than design analysis using only one method [35]. This research is expected to contribute significantly to further research. It can be the basis for developing scientific journals on mobile application user interface (UI) and user experience (UX) design.

RESEARCH METHODS

Data in this study were collected from 30 respondents representing various target user groups of the Waste Bank application. These participants include five representatives from environmental agencies (aged >25 years), ten Waste Bank employees (aged >30 years), ten Waste Bank customers (aged >20 years), and five Informatics students. Environmental agency representatives provide insights into regulatory needs, while Waste Bank employees share practical feedback for daily operational use. Customers represent the general public's perspective, ensuring the app's accessibility, and Informatics students, with foundational UI/UX knowledge, help evaluate design elements. Selecting respondents from these diverse backgrounds ensures a comprehensive and relevant data set for a thorough UI/UX design analysis. Figure 1 shows the stages of the research conducted.

This research implements the User Centered Design method, which has five stages, all focused on the user's needs and experiences. These stages are: Plan the Human Centered Design Process, Understand the Context of Use, Specify User and Organization Requirements, Design Solutions, and Evaluations Against Requirements [25], [26], [27]. At the stage of identifying problems and user needs, the data obtained is analyzed to be used as material in designing UI/UX. After completing the first design and creation, a descriptive evaluation was conducted using the User Experience Questionnaire (UEQ). Based on this assessment, the design was updated to create a better second version, always keeping the user at the center of the process.

The evaluation process of the second design was carried out as in the first step of the process. Then, the results of this evaluation are compared with those of the first design. The design can be declared well completed if the results obtained have met the standards and user needs. However, if users still experience problems, the design process will continue to be repeated until the UEQ results show a good value and meet user needs.

A. User Centered Design (UCD)

The concept of user-centred design (UCD) puts the user at the centre of the process of developing the context, goals, and environment of the system based on user experience [36].

UCD has a five-stage process [29], [30], [37]:

1) Plan the Human Centered Process

At this stage, discussions are held with team members to gain commitment to user orientation in the project development process. This aims to ensure that the design of application systems using UCD can meet user needs.

2) Specify the Context of Use

At this stage, identification of people who will use the product is carried out, including understanding who the user is, his needs, and under what conditions the user will use the product. It aims to ensure that the product design meets the actual situation and user needs.

3) Specify User and Organizational Requirements

At this stage, information or data collection is carried out regarding user and organizational needs. After the information is collected, the data will be presented in various forms, such as narratives, images, diagrams, and others, to facilitate understanding and further analysis.

4) Product Design Solutions

At this stage, solution design is carried out. Researchers create a design as a solution to the system that has been analyzed, ensuring that this design meets the needs and preferences that have been identified in the previous stage.

5) Evaluate Designs Against User Requirements

This is the last stage, where the implemented design is evaluated to determine if the user and organizational goals have been achieved. This evaluation involves testing the

design with actual users and collecting feedback to ensure that the design truly meets the needs and expectations of the users and the organization.

B. User Experience Questionnaire (UEQ)

A user experience questionnaire (UEQ) is a tool used to measure user experience when interacting with a product, such as an application or website. Determination of the number of UEQ samples is done through a sampling process for approximately three weeks. The minimum number of samples to be taken is 20 respondents, according to guidelines adapted from the UEQ Handbook, which recommends a minimum of 20 respondents [38]. The UEQ tool can be run using Microsoft Excel, which allows access to a free downloadable data processing calculator via the official website https://www.ueq-online.org/. The measurement results are the mean value of each UEQ aspect and the Benchmark value [39].

The UEQ contains 26 questions that evaluate the user experience in operating the prototype [40]. These questions cover six aspects of assessment related to user experience. The six aspects assessed in the 26 UEQ questions are as follows [39], [41]:

1) Attractiveness
   This scale measures the overall impression that user have of the app.
2) Perspicuity
   This scale assesses the ease of use of the application that is immediately felt by the user.
3) Efficiency
   This scale evaluates the interaction between the user and the application, specifically in terms of how efficient the application.
4) Dependability
   This scale measures user's feeling regarding the reliability and security of their interactions with the application.
5) Stimulation
   This scale assesses the level of motivation and enjoyment users feel when using the app.
6) Novelty
   This scale evaluates the creativity, innovation, and renewal aspects present in the product or app.

Figure 2 shows a list of each UEQ question. The values for each aspect of the UEQ method can be seen in Table 1.

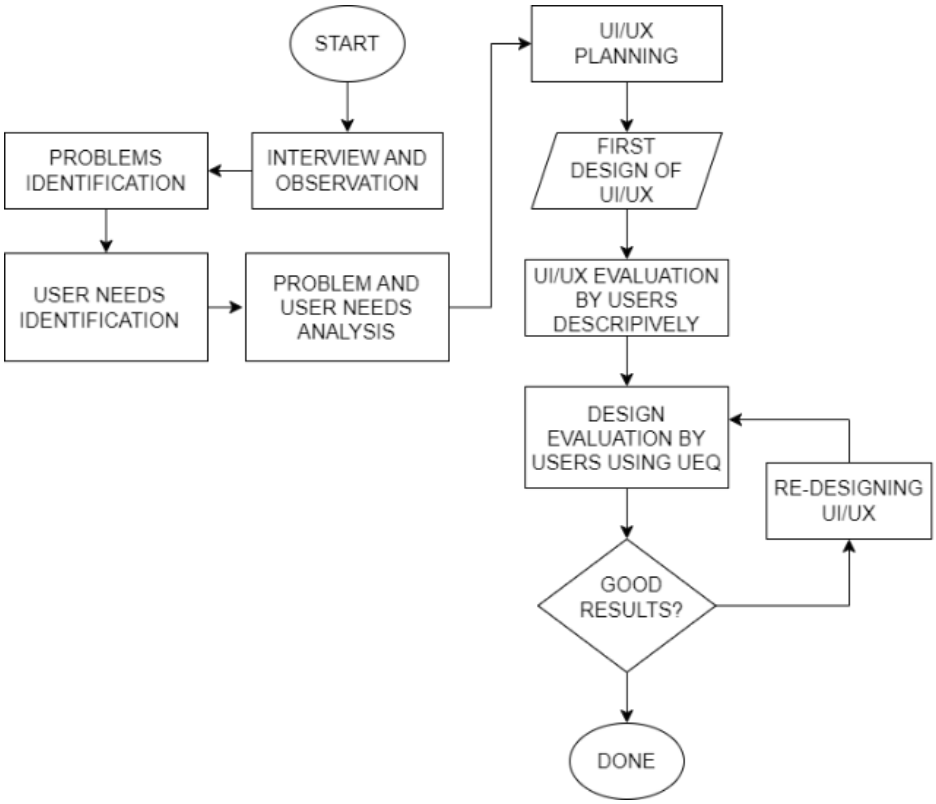

Figure 1. Research Stages

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	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26

Figure 2. Question from User Experience Questionnaire

Table 1. Benchmark Interval for UEQ Scale

	Att.	Per.	Eff.	Dep.	Sti.	Nov.
Excellent	≥1.75	≥1.78	≥1.9	≥1.65	≥1.55	≥1.4
Good	≥1.52 <1.75	≥1.47 <1.78	≥1.56 <1.9	≥1.48 <1.65	≥1.31 <1.55	≥1.05 <1.4
Above Average	≥1.17 <1.52	≥0.98 <1.47	≥1.08 <1.56	≥1.14 <1.48	≥0.99 <1.31	≥0.71 <1.05
Below Average	≥0.7 <1.17	≥0.54 <0.98	≥0.64 <1.08	≥0.78 <1.14	≥0.5 <0.99	≥0.3 <0.71
Bad	<0.7	<0.54	<0.64	<0.78	<0.5	<0.3

The User Experience Questionnaire (UEQ) data processing formula involves several stages. The first stage is determining each respondent's average scale (mean) based on the UEQ scale classification. This process begins by collecting respondents' responses, classifying them, and then calculating the mean for each aspect measured. This ensures accurate data for user experience analysis. The following data processing formula in UEQ is to find the meaning of each respondent.

$$(1) \quad UEQ\ Aspect = \frac{sum\ of\ each\ instrument\ score}{lots\ of\ data}$$

After getting the mean from each respondent, the second stage is to calculate the overall average scale (mean) for each aspect measured by the UEQ, which contains 26 questions.

$$(2) \quad \mathcal{X} = \frac{total\ data}{lots\ of\ data}$$

Description:
- Total score taken from respondents' scores,
- $\mathcal{X}$ = Mean

The third step is calculating pragmatic quality (pq) and hedonic quality (hq). Pq measures functional aspects such as efficiency, perspicuity and dependability, while Hq assesses emotional aspects such as attractiveness, stimulation, and novelty. Evaluating these two qualities provides an overall picture of the user

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experience, covering both practical and emotional aspects. The following formula is used:

(3) $$pq = \frac{sum\ persipicuity,efficiency,and\ dependability\ scores}{lots\ of\ data}$$

(4) $$hq = \frac{sum\ attracttivenes,stimulation,and\ novelty\ scores}{lots\ of\ data}$$

After all stages have been performed, the results of the UEQ scale calculations will be compared to understand their meaning, as shown in Table 1. After knowing the calculation of each scale, the average value of UEQ will be compared again with the benchmark value. This comparison helps identify the areas of strength and weakness of the UI/UX design and provides clear guidelines for further improvement.

RESULT AND DISCUSSION

The first design was based on the results of interviews, problem identification, and user experience obtained from observations at the Environmental Agency. The results of interviews and direct observations show that the Environmental Agency has obstacles in facilitating the community to connect with waste banks easily through mobile applications. In addition, the community needs more information about the existence and benefits of waste banks.

From these problems, the author's idea emerged to develop a waste bank application that gives the community ownership and responsibility in managing waste. After the discussion process was carried out, this waste bank application was named SAKU, which reflects this ownership: Sa means garbage, and Ku means me or I, so SAKU means My Garbage

This application has the main advantage of a garbage pick-up service and a feature to exchange points for money. With diverse target users, this application must have an effective and efficient UI/UX for all groups. The initial design was evaluated by potential users through a questionnaire. Feedback from this evaluation and assessment of the first UI/UX design informed the creation of the second UI/UX design. The two designs will then be compared to demonstrate that the User-Centered Design (UCD) approach is more effective in fulfilling user needs.

A. Results of the First UI/UX Design

At this stage, a prototype was created that includes several main pages: splash screen, login page, home page, waste bank page, and history page. Before displaying the main menu, the application will display a splash screen containing a logo. Next, users must register with several options, such as email and password, or through Google, Facebook, and Apple accounts. If the customer already has an account, they can directly log into the app by entering their username and password. The home page displays critical features such as the total points collected and options for sending, withdrawing, and scanning points. In addition, other menus display features such as waste deposit, waste bank, and transaction history.

On the waste bank page, users can view a map that displays the locations of waste banks in the surrounding area. This feature makes it easier for customers to find information about the advantages of each waste bank.

Furthermore, the history page is designed to display details of the waste the user has deposited, providing a complete overview of the transactions that have been made. This prototype is expected to provide a pleasant user experience and make it easier for people to utilize waste bank services.

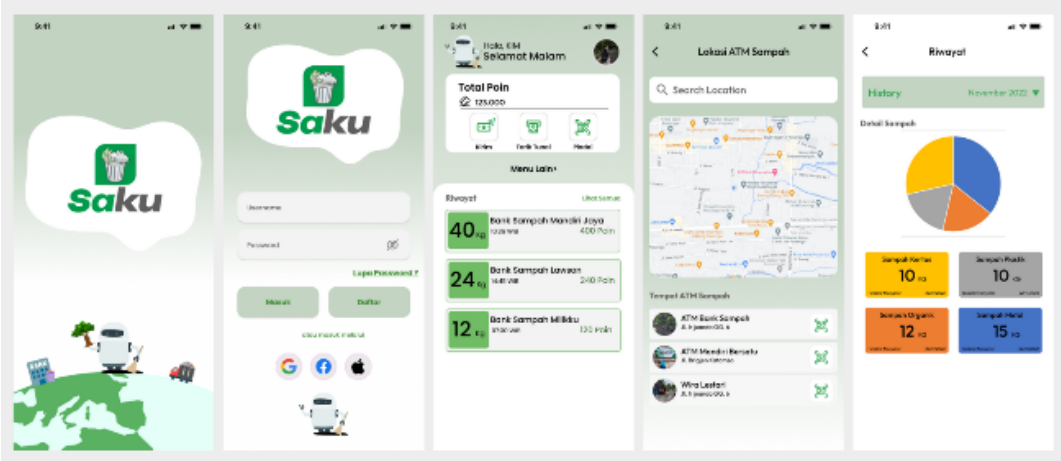

Figure 3. First UI/UX Design

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B. UI/UX Evaluations Results

Feedback from respondents who reviewed the initial prototype indicates that the UI/UX of the SAKU application has an appealing design and offers a positive user experience, particularly in terms of its usefulness to the community. The first design of the application was evaluated with the UEQ to gather both positive and negative insights.

Table 2 shows that of the six aspects measured, attractiveness, dependability, and stimulation received a score of >= 1.2, aspects of perspicuity and efficiency received a score of >= 1.3, and novelty received the lowest score of >= 1.0. From these data, the application's first UI/UX design still needs to be developed, especially the novelty part, because it gets the lowest score. According to some respondents, the colors in the first design are less attractive and arousing to use the application. In addition, another suggestion from respondents is that the home menu should display all the features so that users can quickly use the features provided. That way, the second design stage will not change the design much, but researchers need to improve the balance of the design to be better and as expected by users.

Table 2. First Design UEQ Score

UEQ Scales (Mean and Variance)		
Attractiveness	1,289	0,23
Perspicuity	1,350	0,17
Efficiency	1,325	0,24
Dependability	1,250	0,21
Stimulation	1,233	0,32
Novelty	1,050	0,16

C. Results of the Second UI/UX Design

At this stage, a second design is created based on the insights gained from the prior evaluation. By analyzing user needs, the User-Centered Design method is used as a guide to create an optimal application design.

After successfully redesigning the prototype, the app's color scheme and typography were the most significant changes. In addition, it displays the home page main features based on users' suggestions in the first evaluation. Thus, these changes are anticipated to enhance the overall user experience, making the app more functional and attractive. Here is a look at the second design of the SAKU app.

Based on the SAKU application design results, the next step is to evaluate the UI/UX prototype using UEQ. This second evaluation was conducted with the same 30 participants.

Table 3 shows that of the six aspects measured, attractiveness, perspicuity, efficiency, and stimulation scored >= 2.00, and then the dependability and novelty aspects scored >=1.9.

Table 3. Second Design UEQ Score

UEQ Scales (Mean and Variance		
Attractiveness	2,200	0,19
Perspicuity	2,117	0,19
Efficiency	2,025	0,09
Dependability	1,908	0,16
Stimulation	2,033	0,10
Novelty	1,958	0,16

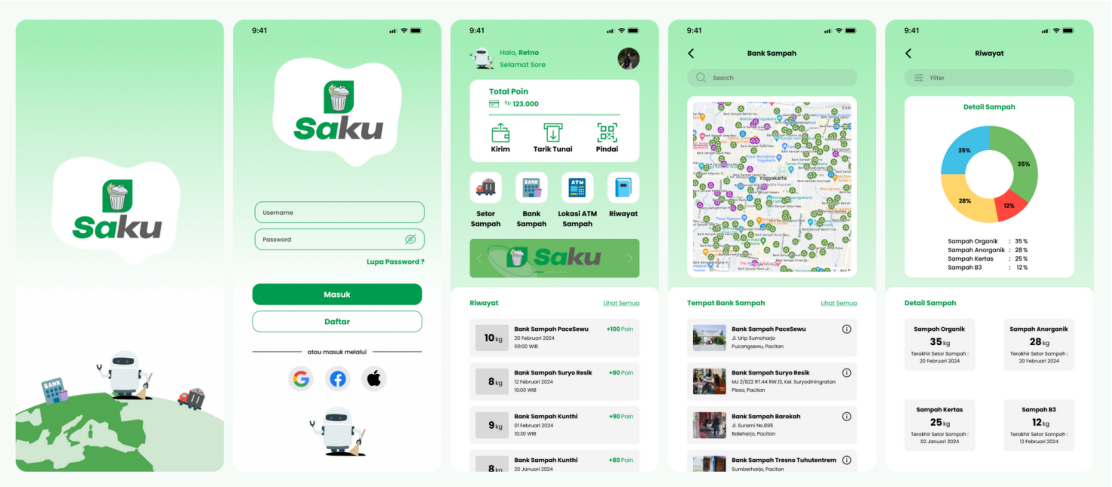

Figure 4. Second UI/UX Design

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D. UEQ Comparison Results

The comparison between the first and second UI/UX designs is shown in Table 4. The comparison of UEQ scores shows a significant improvement in all aspects of the second UI/UX design. The assessment of the first design (before using UCD) only reached "Above Average", with 25% of results better and 50% worse. In contrast, the second design (using UCD) produced a consistent assessment of "Excellent", within the range of the 10% best results. One prominent comparison is the attractiveness aspect, which increased from 1.29 to 2.20, indicating that users find the second design more attractive. The novelty aspect also experienced a significant increase from 1.05 to 1.96, reflecting the innovative appeal of the second design. This increase in novelty not only indicates the potential of the UCD process but also excites us about the innovative appeal of the second design. The improvement in all these aspects indicates that the design developed using the UCD process is more effective in meeting user needs.

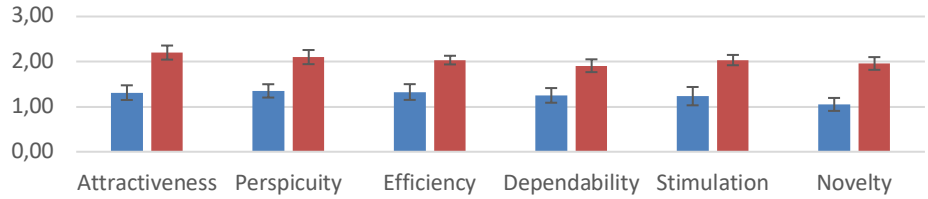

Figure 5. UEQ Comparasion Result

Table 4. Design Comparasion Result

Aspect	First Design Score	Second Design Score	Difference	Impact Analysis of UCD
Attractiveness	Above Average (1.29)	Excellent (2.20)	+0.91	Color scheme and typography changes are more appealing and in line with user preferences. Increased appeal and better visual development.
Perspicuity	Above Average (1.35)	Excellent (2.12)	+0.77	Addition of key features on the home page. Make the application easier to understand and use, assisting users in navigation and use of the features provided.
Efficiency	Above Average (1.33)	Excellent (2.03)	+0.70	The workflow in the app is simplified, and unnecessary steps are reduced. By improving the app's efficiency, users can achieve their goals quickly and easily.
Dependability	Above Average (1.25)	Excellent (1.91)	+0.66	Improves consistency of application results and responses. Increase user confidence in the system, as the application can be relied upon to provide a stable and predictable experience.
Stimulation	Above Average (1.23)	Excellent (2.03)	+0.80	It is adding interactive elements such as vouchers. It can motivate users to continue using the app.
Novelty	Above Average (1.05)	Excellent (1.96)	+.91	Introducing new features that are innovative and different from similar apps such as garbage pickup

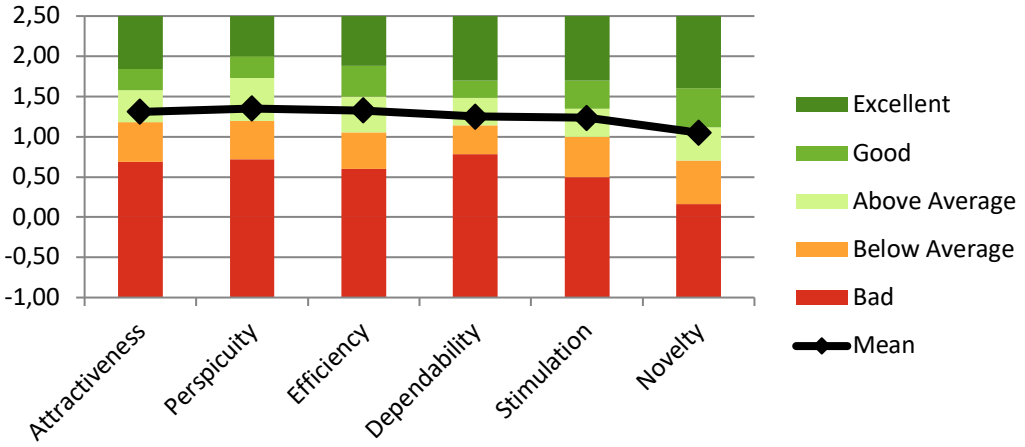

Figure 6. First Design Benchmark Results

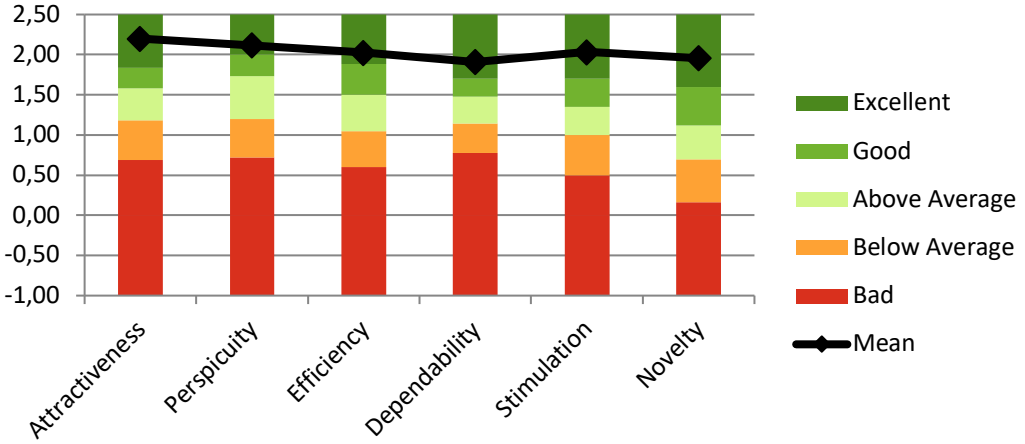

Figure 7. Second Design Benchmark Results

CONCLUSION

The study results concluded that the combination of User Centered Design (UCD) and User Experience Questionnaire (UEQ) significantly enhances the UI and UX designs. The UCD approach ensures that the design is rooted in the user's needs and preferences, while UEQ measures the overall quality of the user experience. This synergy not only improves the functional aspects of attractiveness, perspicuity, and efficiency but also enhances the emotional aspects of stimulation and novelty, leading to a more effective design. The difference in UEQ measurement results in the first and second designs showed an average increase of 0.79, underscoring the substantial improvement in UI/UX quality. However, this study also highlights the need to consider the geography of users and its influence on local culture in further research. Therefore, it is imperative to develop UI/UX designs that are culturally sensitive and oriented towards the local culture of users.

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