

Eco Cycle Mobile: A Design Thinking Approach for Sustainable User Interface and User Experience Design

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ABSTRACT

The Eco Cycle system is a mobile-based circular economy platform designed to increase public participation in sustainable waste management activities. The development of a mobile-based Eco Cycle application is urgent because it addresses usability and accessibility issues and supports sustainable behavior change through interactive, educational, and collaborative digital experiences. The objective of the research is to develop a User Interface and User Experience prototype for a circular-economy-based Eco Cycle mobile application to increase public participation in sustainable waste management, environmental engagement, and circular-economy activities. The research method employs a Design Thinking approach comprising Empathy, Definition, Ideation, Prototype, and Testing. The application prototype integrates several key features: ECOSell and ECOBuy for waste buying and selling services, ECOducation for environmental education, ECOcommunity for community collaboration, ECOPlanner for waste management planning, and ECOPoint as a participation-based system. The results of the study indicate that a usability evaluation using the User Experience Questionnaire and an open-ended questionnaire yielded positive user experiences across all UEQ dimensions. The highest scores for the attractiveness (1.87) and stimulation (1.80) dimensions were categorized as very good. The efficiency dimension scored 1.85, dependability 1.53, and novelty 1.26, categorized as good. Clarity scored 1.71, categorized as above average. Additional usability analysis demonstrated high task completion rates and positive user perceptions of the ease of transactions, system resources, and environmental interaction features. The study concludes that the Design Thinking approach is effective for developing a user-centric mobile application that supports environmentally friendly behavior and increases community participation in circular-economy-based waste management.

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1. INTRODUCTION

The increasing volume of waste generation and the low efficiency of recycling systems have become major challenges to achieving sustainable development and implementing a circular economy. In Indonesia, waste management systems still face significant limitations, including fragmented recycling supply chains, limited public participation, inadequate digital integration, and low environmental awareness. These challenges affect the continuity of circular economy businesses, which depend heavily on stable recyclable material supply chains and active community participation. Inefficient waste collection systems, a lack of real-time monitoring, and limited collaboration among communities, recyclers, and environmental organizations further undermine the effectiveness of sustainable waste management practices.

Digital technology has emerged as an important approach for improving environmental management systems and supporting sustainable behavior transformation. Various digital waste management platforms have been developed to connect communities, recyclers, and environmental organizations through information-sharing and waste-transaction services. In Indonesia, several Eco Cycle-based platforms already exist as websites. These systems provide features such as access to waste information, recycling transactions, and environmental collaboration. However, despite their functional capabilities, website-based platforms still present several limitations related to accessibility, flexibility, and user interaction quality [1].

The rapid growth of smartphone usage has significantly shifted user behavior toward mobile-based interaction [2]. Mobile applications provide advantages, including portability, real-time communication, location-based services, camera integration, and faster interaction processes [3]. These capabilities make mobile platforms better suited to supporting dynamic environmental activities such as waste reporting, recycling transactions, environmental education, and collaborative community engagement. Nevertheless, many existing environmental applications focus primarily on technical functionality and operational processes while neglecting user experience quality, behavioral engagement, and long-term sustainability participation [2]. Previous studies on waste management applications and environmental digital platforms have demonstrated that usability and user engagement significantly influence user adoption and sustainability participation. Applications with poor navigation structures, complex workflows, limited interaction feedback, and insufficient motivational systems often experience low long-term usage and weak environmental engagement [4]. Studies in Human-Computer Interaction also emphasize that effective digital sustainability platforms require intuitive interaction design, emotional engagement, and user-centered experiences to encourage sustainable behavioral adoption [4, 5].

Several studies have implemented User Interface/User Experience (UI/UX) design approaches in environmental applications using User-Centered Design and Design Thinking methodologies [6, 7]. Previous research reported improvements in usability and interaction efficiency through iterative design approaches [8, 9]. However, most existing studies focus primarily on usability optimization and interface visualization without integrating broader sustainability-oriented interaction mechanisms such as environmental education, gamification, community collaboration, and behavioral motivation systems within a unified mobile platform [10, 11].

Furthermore, although the Design Thinking approach has been widely applied in UI/UX development [12, 13], its implementation in circular economy mobile applications remains limited, particularly regarding sustainability-oriented interaction design and behavioral engagement analysis. Most previous studies only evaluate interface usability without deeply analyzing environmental participation, green behavior stimulation, or sustainability engagement outcomes [14, 15]. This condition indicates an unresolved issue regarding how user-centered mobile interaction design can effectively support participation in the circular economy and environmentally responsible behavior. From a theoretical perspective, this study integrates several conceptual foundations. First, the User-Centered Design (UCD) approach emphasizes that systems should be developed based on user needs, behaviors, and usability expectations [16, 17]. Second, Human-Computer Interaction (HCI) theory highlights the importance of interaction efficiency, cognitive simplicity, and emotional engagement in digital system adoption [5, 6]. Third, the Technology Acceptance Model (TAM) explains that perceived usefulness and perceived ease of use significantly influence user acceptance of technology [1]. Fourth, sustainable behavior theory emphasizes that environmental participation can be strengthened through motivational systems, social influence, education, and behavioral reinforcement mechanisms.

Based on these gaps and limitations, this study proposes developing a mobile-based Eco Cycle application prototype using the Design Thinking approach. The application integrates waste management transactions, environmental education, collaborative interaction, reward systems, and sustainability engagement features into a single mobile ecosystem to improve usability and encourage participation in the circular economy.

2. RESEARCH METHOD

This research employed the Design Thinking approach to develop the UI/UX prototype of the Eco Cycle mobile application. Design Thinking is a user-centered methodology that emphasizes understanding user needs, identifying problems, and generating innovative, effective, and efficient solutions [13]. The stages in the Design Thinking process consist of Empathize, Define, Ideate,

Design Prototype, and Test Design. The overall research flow is illustrated in Figure 1.

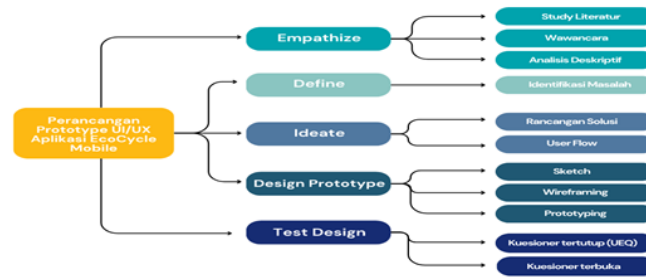


Figure 1. Research Flow

2.1. Empathize

The empathy stage is the initial phase of the Design Thinking Approach, which aims to gain an in-depth understanding of user needs, behaviors, motivations, and challenges related to waste management activities and the use of digital applications. This stage consists of three main activities, namely literature review, interviews, and descriptive analysis. The literature review stage was conducted to examine theories, previous studies, and related works on UI/UX design, Design Thinking methodology, mobile application development, and circular economy systems [7, 9]. This review also examined prior studies on waste management applications and the development of the Eco Cycle platform. The findings from the literature review serve as a basis for determining the appropriate design approach, identifying user-centered design principles, and formulating relevant application features. The interview stage uses a qualitative approach, namely semi-structured interviews, to gather user insights. Respondents were selected using purposive sampling to ensure participants have relevant experience and knowledge related to waste management activities and the use of digital applications. A total of [7] respondents participated in this study, consisting of: General users, members of environmental communities, waste bank managers, and active digital application users. The inclusion criteria for respondents were: Minimum age (18-45) years; active use of smartphones or mobile applications; experience, awareness, or interest in waste management activities; and Willingness to participate in the interview process. The interviews explored user behavior, challenges in waste disposal and recycling, accessibility issues, and expectations regarding the Eco Cycle mobile application's features and usability. A descriptive analysis phase was conducted to organize and interpret the interview findings into structured information regarding user behavior, needs, and preferences. This analysis aimed to identify common problems, user expectations, interaction patterns, and opportunities to improve waste management activities through the Eco Cycle mobile application. The results of this analysis served as the basis for defining user problems and developing design solutions in the next phase.

2.2. Define

At the Define stage, the collected qualitative data were synthesized through affinity diagramming to identify recurring patterns and prioritize user problems. The identified issues were then translated into user needs and problem statements. This analytical process ensured that the proposed design solutions were systematically derived from empirical findings rather than subjective assumptions.

2.3. Ideate

The Ideate stage adopted a structured brainstorming and feature prioritization process. Feature selection was based on user needs, frequency, feasibility, and expected usability impact. User Flow development also considered usability principles such as simplicity, consistency, and efficiency to ensure effective navigation design.

2.4. Design Prototype

The prototype development process followed iterative design principles. Initial sketches and wireframes were evaluated internally before being transformed into high-fidelity interactive prototypes in Figma. Iterative revisions were made based on feedback from preliminary evaluations to improve interface consistency, usability, and accessibility.

2.5. Test Design

The design test used the UEQ (User Experience Questionnaire). The evaluation phase involved 30 respondents testing an interactive prototype. The UEQ instrument was chosen because it provides a comprehensive measurement of user experience across six dimensions: attractiveness, clarity, efficiency, reliability, stimulation, and novelty [18, 19]. Compared to the SUS, which primarily focuses on usability, the UEQ enables a broader evaluation encompassing both pragmatic and hedonic aspects of the user experience, making it more suitable for assessing the quality of UI/UX prototypes [20]. The UEQ instrument has also demonstrated validity and reliability in previous UI/UX studies [21, 22]. Reliability testing in this study was conducted using Cronbach's Alpha to measure internal consistency for each UEQ scale. A Cronbach's Alpha value greater than 0.70 indicates acceptable reliability. An open-ended questionnaire was distributed after the prototype testing to obtain qualitative feedback regarding user impressions, interface clarity, feature usability, and suggestions for improvement [23]. Qualitative responses complemented the quantitative UEQ results and supported the iterative refinement of the prototype.

2.6. Data Analysis

Quantitative data obtained from the UEQ were analyzed using descriptive statistical methods, including mean scores and standard deviation for each evaluation scale [18]. Benchmarking analysis based on the UEQ Data Analysis Tool was also conducted to categorize results into Excellent, Good, Above Average, Below Average, or Bad categories [19]. In addition, reliability analysis using Cronbach's Alpha was performed to evaluate the consistency of questionnaire responses. Qualitative feedback from open-ended questionnaires was analyzed using thematic analysis to identify recurring suggestions and usability issues [23].

2.7. Validity and Reliability

To ensure the quality, validity, and reliability of the research, assessments were conducted. Content validity was established through expert review involving UI/UX practitioners and academic supervisors who evaluated the relevance of [24] questionnaire items and prototype components. Reliability testing of the UEQ instrument was conducted using Cronbach's Alpha coefficient. The obtained reliability values above the acceptable threshold indicated that the instrument consistently measured user experience perceptions [25].

2.8. Ethical Consideration

This study considered ethical aspects throughout the research process. All participants were informed about the research objectives and procedures before participating. Participation was voluntary, and respondents provided informed consent prior to interviews and prototype testing. Participant confidentiality and anonymity were maintained by ensuring that personal data were not disclosed in the research report. All collected data were used solely for academic and research purposes.

3. RESULT AND ANALYSIS

3.1. Empathize

The Empathize stage consisted of a literature review, interviews, and descriptive analysis. This stage aimed to obtain a comprehensive understanding of user behavior, needs, motivations, and challenges related to waste management and digital application usage. The findings from this stage served as the foundation for designing a user-centered UI/UX prototype for the Eco Cycle Mobile application. Literature Review foundation regarding UI/UX design principles, Design Thinking methodology, user-centered design approaches, and digital waste management systems. Previous studies indicated that the Design Thinking approach is effective in identifying user needs and improving usability in mobile application development [9, 26]. In addition, studies on environmental applications emphasized the importance of intuitive interfaces, accessibility, and interactive educational features in encouraging public participation in sustainable behavior. The literature review also identified that reward-based systems, social collaboration features, and educational content significantly influence user engagement in environmental applications [27, 28]. These findings became the basis for determining the design direction and feature development of Eco Cycle Mobile [11].

Semi-structured interviews were conducted with 15 participants selected using purposive sampling techniques [29]. The respondents consisted of: Five general community members involved in household waste management, five members of environmental communities and waste bank managers, and five active users of digital applications. The participant selection criteria included: Aged between 18 and 45 years, Familiar with smartphone usage, actively involved in waste management or environmental activities, and

willing to participate voluntarily. The interviews explored waste management habits, challenges in recycling, digital readiness, user expectations, and preferred application features. Each interview lasted approximately 20-30 minutes and was documented for further analysis. The interview findings revealed several recurring issues, including difficulties accessing recycling services, a lack of structured waste collection systems, limited information on waste management locations, and low public motivation to consistently participate in environmental activities. Respondents also expressed the need for applications that are easy to use, visually attractive, educational, and capable of providing direct benefits such as incentives and community engagement.

Descriptive thematic analysis was conducted by integrating findings from the literature review and interviews. The analysis identified several major themes related to user behavior and application expectations, including ease of use and simple navigation, real-time information accessibility, incentive-based engagement systems, community collaboration features, Interactive environmental education, and transparent waste transaction processes. The analysis demonstrated that users require a digital platform that not only facilitates waste management activities but also motivates sustainable environmental behavior through interactive and rewarding experiences. These findings became the basis for defining user problems and determining feature priorities in the next stage.

3.2. Define

The Define stage focused on identifying and formulating the core problems users experience, based on findings from the Empathize stage. Data from interviews, literature studies, and observations were synthesized using affinity diagram analysis to identify recurring patterns and prioritize user needs [7]. The analysis identified the following primary problems: Limited availability of accessible and user-friendly digital waste management systems; inefficient waste collection and recycling processes; limited access to information regarding waste management locations; lack of motivational and reward systems for users; low environmental digital literacy and awareness; limited transparency and collaboration among environmental communities; and accessibility limitations in existing website-based platforms. These findings were then translated into problem statements using a framework to ensure that the resulting solutions were directly aligned with user needs. The Define stage provided a structured analytical basis for developing the application features and interaction flows in the Ideate stage.

3.3. Ideate

The Ideate stage focused on generating ideas and designing application solutions based on the identified problems and user needs. A user-centered design approach was applied to ensure that every proposed feature addressed actual user challenges [16, 17]. This stage produced solution concepts, feature structures, and user interaction flows that later became the foundation for the prototype development process. The solution design process involved brainstorming and feature prioritization based on the frequency of user needs, usability impact, and implementation feasibility. The resulting solution concepts are described as follows: To address the problem of limited access to user-friendly digital systems, the application was designed as a mobile-based platform with a centralized dashboard that provides quick access to all main features, including waste management services, educational content, and community activities. The ECOSell feature was developed to improve the efficiency of waste collection and recycling transactions. Users can upload waste photos, select waste categories, determine drop-off locations, receive estimated prices, and monitor transaction status in real time [9]. The ECOBuy feature was designed to support the purchase of recycled products through a simplified transaction process. Users can browse recyclable product catalogs, view product details, add items to their cart, and complete purchases via integrated checkout. The ECOPlanner feature helps users organize waste deposit schedules and environmental activities. This feature allows users to set schedules, determine waste types and locations, upload activity documentation, and receive reward points upon completion. The ECOPoint system was developed to increase user motivation through gamification mechanisms. Users can earn points through various activities, including daily check-ins, waste-selling transactions, participation in environmental challenges, and completing educational quizzes. The ECOducation feature provides interactive educational materials, including articles, infographics, quizzes, and environmental challenges. Meanwhile, ECommunity was designed as a collaborative platform where users can share activities, join environmental events [29], interact with communities, and monitor collective environmental initiatives.

User Flow diagrams were created to visualize user interactions within the application and to ensure logical, structured, and efficient navigation. The main user flows include: Registration and login flow, ECOSell transaction flow, ECOBuy purchasing flow, ECOPoint reward redemption flow, ECOPlanner scheduling flow, ECOducation learning and quiz flow, Profile management flow. The user flow design ensured that each interaction process remained intuitive, simple, and aligned with user expectations identified during the Empathize stage.

3.4. Design Prototype

The Design Prototype stage translated conceptual solutions into visual and interactive interface designs. This stage consisted of Sketching, Wireframing, and Interactive Prototyping processes. The following is an explanation of each phase. Initial sketches were created to visualize layout structures, navigation flows, and feature placements. The sketches focused on usability, navigation clarity, and interaction simplicity. The main dashboard sketch included seven primary features: ECOSell, ECOBuy, ECommunity, ECOducation, ECOplanner, ECOPoint, and ECOBot. Wireframes were developed from the sketch layouts, incorporating additional structural details. The wireframes focused on content hierarchy, navigation consistency, and interface functionality without emphasizing visual aesthetics. The login page wireframe included the application logo placement, email and password input fields, a login button, and registration access for new users. The wireframe in Figure 2.

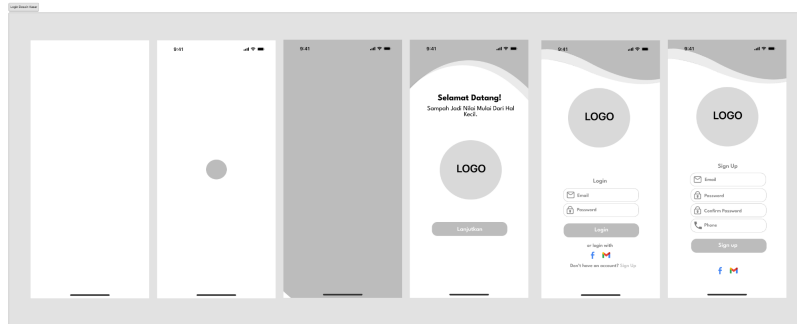


Figure 2. Login Page Wireframe

High-fidelity interactive prototypes were developed using Figma software [30, 31]. The prototype simulated realistic user interactions and implemented user-flow-based navigation structures [32]. Iterative revisions were conducted based on internal evaluations before usability testing [15]. High-fidelity interactive prototypes begin with the logo design, color palette, and application prototype flow.

The Eco Cycle Mobile logo design (named "RosokIn") is designed to represent sustainability, environmental awareness, and community collaboration. The logo incorporated circular shapes, leaf elements, and wave patterns symbolizing recycling and ecological continuity. The logo design in Figure 3.



Figure 3. Eco Cycle Mobile Logo

The application color palette consisted of: Primary colors: turquoise blue, golden yellow, and dark blue. Secondary colors: pale blue and natural blue variations. Neutral colors: white, grey, and cream tones. The selected colors were intended to create a modern, environmentally friendly, and visually comfortable interface while maintaining readability and interface consistency, in Figure 4.



Figure 4. Color Palette

The prototype flow visualizes user interactions across the app's key features. The prototype flow starts with the first, Login and Onboarding flow where Users access the app through the onboarding screen, account registration, and login page. Second, the ECOSell Feature flow where Users select the type of waste, upload photos of waste, determine the pickup location, and confirm the transaction. Third, the ECOBuy Feature flow where Users browse recycled products, view product details, and complete purchases through the checkout process. Fourth, the ECOCommunity Feature flow where Users interact through community discussions, environmental activities, and collaborative posts. Fifth, the ECOPoint Feature flow where Users monitor points earned, redeem rewards, and review activity history. Sixth, the ECOeducation Feature flow where Users access educational materials and complete quizzes to increase environmental knowledge. Lastly, the ECOPlanner Feature flow where Users create waste deposit plans, upload supporting documents, and monitor activity history. This flow ensures that each interaction process remains intuitive, simple, and aligned with user expectations.

3.5. Test Design

The testing phase evaluates the quality of the user experience and identifies areas for interface improvement. Evaluation combines quantitative and qualitative approaches. Evaluation through User Experience Questionnaire (UEQ) and open-ended questionnaires. The prototype testing for the User Experience Questionnaire included 47 respondents who interacted with the application prototype prior to completing the UEQ instrument. The UEQ was selected because it evaluates both pragmatic quality (efficiency, dependability, perspicuity) and hedonic quality (stimulation, novelty, attractiveness), making it more comprehensive for UI/UX evaluation compared to usability-focused instruments such as SUS [18, 20]. Reliability analysis was conducted using Cronbach's Alpha to measure internal consistency across UEQ scales. All scales achieved reliability coefficients above 0.70, indicating acceptable reliability. The UEQ results in Table 1.

Table 1. Average UEQ Scores

Scale UEQ	Average Score	Interpretation
Attractiveness	1.87	Excellent
Perspicuity	1.71	Above Average
Efficiency	1.85	Good
Dependability	1.53	Good
Stimulation	1.80	Excellent
Novelty	1.26	Good

The results indicate positive evaluations across all dimensions. Attractiveness and stimulation achieved the highest scores and were categorized as excellent, indicating that users perceived the application as visually appealing and engaging. Efficiency, dependability, and novelty were categorized as good, demonstrating that users considered the application functional, reliable, and sufficiently innovative. Perspicuity obtained an above-average score, indicating that the application was generally easy to understand, although several respondents suggested improving onboarding guidance for first-time users [31, 33]. To strengthen interpretation, the benchmark categories provided in the UEQ benchmark dataset were applied [19], which are in Table 2.

Table 2. Interpretation of UEQ Scores (Benchmark)

Scale	Bad	Below Average	Above Average	Good	Excellent
Attractiveness	< 0.69	0.69 – 1.18	1.18 – 1.58	1.58 – 1.84	> 1.84
Perspicuity	< 0.72	0.72 – 1.20	1.20 – 1.73	1.73 – 2.00	> 2.00
Efficiency	< 0.60	0.60 – 1.05	1.05 – 1.50	1.50 – 1.88	> 1.88
Dependability	< 0.78	0.78 – 1.14	1.14 – 1.48	1.48 – 1.70	> 1.70
Stimulation	< 0.50	0.50 – 1.00	1.00 – 1.35	1.35 – 1.70	> 1.70
Novelty	< 0.16	0.16 – 0.70	0.70 – 1.12	1.12 – 1.60	> 1.60

Overall, the benchmark comparison demonstrated that all evaluation scales achieved scores above the average threshold, indicating positive user experience quality across the application in Figure 5.

An open-ended questionnaire was distributed to gather qualitative feedback on interface design, feature usability, and suggestions for improvements. The analysis results are summarized in Table 3.

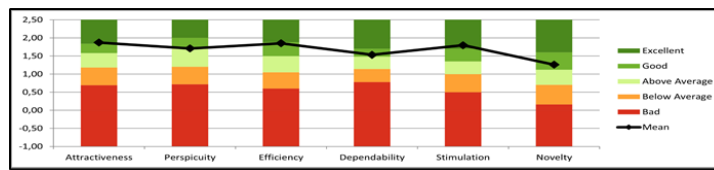


Figure 5. UEQ Score Comparison Chart with Benchmark

Table 3. Most Appealing Parts of the App According to Respondents

Interesting Part	Reason	Example Statement
<i>ECOSell / Sell Waste</i>	The most attractive features are that it provides immediate financial benefits and that the process is clear.	“ECOSell. . . we can sell trash for money”, “the trash selling feature is very helpful.”
<i>ECOMmunity</i>	Liked because there are social interactions, events, relationships, and an attractive appearance.	“ECOMmunity because you can socialize”, “Attractive appearance for users.”
<i>ECOducation</i>	It is interesting because it provides simple, clear education and includes quizzes.	“The ECOducation section is simple in design”, “contains educational and interactive quizzes.”
Dashboard / Home page	Graphs, points, and visual displays are considered engaging and informative.	“The homepage looks attractive and interactive.”
Main course (ECOSell, ECOBuy, ECOPoint, etc.)	The main menu layout is easy to understand and neat.	“Most attractive main menu layout”

The qualitative findings reinforced the UEQ results, showing that users appreciated the practical benefits, visual appeal, educational value, and social interaction features of the application. Overall, the evaluation results indicate that the Eco Cycle Mobile UI/UX prototype successfully addressed user needs and demonstrated strong potential as an interactive digital platform supporting waste management and circular economy implementation.

4. CONCLUSION

This study successfully developed a UI/UX prototype for the Eco Cycle Mobile application using the Design Thinking approach as a user-centered design methodology. The research demonstrates that integrating waste management services, environmental education, reward systems, and community collaboration into a single mobile platform can enhance user engagement and support participation in the circular economy. The results indicate that the Design Thinking approach was effective in translating user needs into an intuitive and interactive mobile interface. The usability evaluation involving 47 respondents showed positive results across all User Experience Questionnaire (UEQ) dimensions. The highest scores were obtained in attractiveness (1.87) and stimulation (1.80), categorized as excellent, indicating that users perceived the application as visually appealing, engaging, and motivating. Efficiency (1.85), dependability (1.53), and novelty (1.26) achieved good scores, while perspicuity (1.71) was categorized as above average. These findings demonstrate that the application provides satisfactory usability performance while maintaining positive emotional engagement.

Scientifically, this study contributes to the field of Human-Computer Interaction and sustainable digital system design by proposing an integrated UI/UX framework. This framework combines circular economy principles, gamification-based behavioral motivation, community-driven interaction, and sustainability-oriented mobile user experience design. Theoretically, the findings strengthen the understanding that user-centered design approaches, such as Design Thinking, can improve usability and sustainability engagement in environmental applications. In practice, this research contributes to the development of digital sustainability platforms that support waste management activities, increase environmental awareness, and encourage active community participation in circular economy practices. The findings may serve as references for developers, researchers, and policymakers interested in designing sustainability-oriented mobile applications.

The novelty of this research lies in integrating transactional waste management, environmental education, reward systems, and collaborative environmental engagement into a unified mobile application ecosystem designed to encourage sustainable behavior and participation in the circular economy. Eco Cycle Mobile incorporates behavioral engagement mechanisms through gamification, interactive education, and social collaboration features.

This study has several limitations. First, the evaluation involved only 47 respondents, which limits the generalizability of the findings across broader populations. Second, the research focused on prototype-based evaluation rather than real-world system implementation, meaning that long-term usability and behavioral adoption could not yet be fully measured. Third, the usability

evaluation primarily relied on descriptive analysis and UEQ benchmarking without deeper inferential statistical testing. In addition, the study did not conduct longitudinal observation to measure sustained environmental behavior change over time. Future research is recommended to expand both the system's technical implementation and its analytical depth. Several potential future developments include: integration of Artificial Intelligence (AI)-based waste classification systems, internet of Things (IoT)-based real-time waste tracking and smart waste monitoring, adaptive gamification systems based on user behavioral patterns, longitudinal behavioral adoption studies to measure sustainability habit formation, comparative usability evaluation using multiple UX evaluation methods such as SUS, TAM, and heuristic evaluation, real-time sustainability analytics dashboards for monitoring environmental impact, heuristic evaluation, machine learning-based personalized environmental recommendation systems, social engagement analytics to measure collaborative participation and digital environmental influence. Future studies are also encouraged to incorporate deeper usability metrics, such as task completion time, cognitive workload analysis, interaction efficiency, error rate analysis, and user retention intention, to obtain more comprehensive insights into user behavior and long-term sustainability engagement.

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All authors contributed significantly to the writing of this article. They were actively involved in drafting and developing the content presented in the manuscript. In addition, all authors participated in revising and refining the article to ensure its clarity and accuracy.

6. DECLARATIONS

AI USAGE STATEMENT

The authors acknowledge that Artificial Intelligence tools, including ChatGPT (developed by OpenAI) and Claude.ai, were used to support language refinement, grammar correction, and paraphrasing during manuscript preparation. The authors confirm that all ideas, data interpretations, and conclusions are their own and not generated by the AI tool.

AUTHOR CONTRIBUTION

Rini Indriati, the first author, conceived and designed the research, conducted data collection and analysis, and drafted the initial manuscript. Ning Inge Halimah Silva, the second author, contributed to the experimental design, performed statistical analysis, and provided critical revisions to improve the manuscript. Author 3, Delilla Anandita, offers guidance on framing the research, critically reviews the manuscript, and ensures it meets academic standards for publication.

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The authors declare no conflict of interest regarding the publication of this article.

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