Development and Evaluation of Segresmart: An AI-Enabled Mobile Application for Improving Household Waste Segregation Behavior

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ABSTRACT

Improper household waste segregation remains a persistent challenge that undermines recycling efficiency and sustainable solid waste management, particularly in urban communities. This study presents the development and evaluation of SegreSmart, an AI-enabled mobile application designed to improve household waste segregation behavior through real-time waste identification and actionable disposal guidance. Guided by a design-and-development research framework, the system integrates image-based artificial intelligence, a user-centered mobile interface, and behavioral analytics to support informed segregation decisions at the point of disposal. The application was evaluated using a quasi-experimental pre-test and post-test design involving urban household participants over a four-week intervention period. Behavioral outcomes were assessed in terms of segregation accuracy, frequency of correct segregation, and perceived behavioral control, complemented by system usage logs and AI performance metrics. Results indicated significant improvements across all behavioral indicators following the intervention, with users demonstrating higher accuracy and consistency in waste segregation and increased confidence in waste classification decisions. The AI model achieved high classification accuracy under real-world conditions, while the human-in-the-loop design, incorporating confidence indicators and manual overrides, enhanced user trust and learning. High usability and acceptance ratings further confirmed that the application was intuitive and suitable for routine household use. Overall, the findings demonstrate that Segre Smart is a functional, usable, and data-driven mobile intervention capable of supporting positive behavioral change in household waste segregation. The study contributes empirical evidence on the effectiveness of AI-enabled mobile applications as decision-support tools for sustainable household waste management. It provides a foundation for future large-scale deployment and longitudinal evaluation.

Keywords: artificial intelligence, mobile application, household waste segregation, waste classification, waste segregation system, sustainable waste management, human-in-the-loop systems

INTRODUCTION

The continuous growth of urban populations and changes in consumption patterns have led to a significant increase in the volume and complexity of household solid waste. In many developing urban environments, improper household waste segregation remains a persistent challenge, undermining recycling initiatives and reducing the overall efficiency of solid waste management systems. When waste is not segregated at the source, recyclable materials are often contaminated, recovery rates decline, and a greater proportion of waste is directed to landfills or informal disposal sites, resulting in environmental degradation and public health concerns [8], [20].

Although municipal governments have invested in waste collection and disposal infrastructure, these efforts are frequently compromised by limited household participation in proper waste segregation practices. Prior research indicates that household waste segregation behavior is shaped by a combination of psychological, informational, and contextual factors, including environmental attitudes, perceived convenience, clarity of waste classification guidelines, and access to immediate feedback during disposal [2], [13], [16]. A commonly observed issue is the intention–behavior gap, wherein individuals express positive intentions toward recycling but fail to consistently apply proper segregation practices in their daily routines [9], [15].

Mobile technologies have emerged as promising tools for addressing this behavioral gap by supporting environmentally responsible decision-making at the point of action. Mobile applications can deliver real-time guidance, personalized recommendations, and educational content that enhance users' perceived control and confidence in waste segregation decisions. Empirical studies have demonstrated that mobile app–based interventions can positively influence recycling and waste separation behavior by reducing uncertainty and increasing user engagement [5], [10]. However, many existing applications rely heavily on static information or self-reported actions, which limits their effectiveness in guiding users during actual household waste disposal activities.

Recent advances in artificial intelligence (AI), particularly in image-based waste classification using deep learning, offer new opportunities to improve the accuracy of household waste segregation. Lightweight convolutional neural network models have shown strong performance in classifying common waste categories while remaining suitable for deployment on mobile devices with limited computational resources [4], [18]. By embedding AI-based waste identification into mobile applications, users can receive immediate, context-specific feedback on waste type and appropriate segregation, thereby reducing cognitive load and minimizing classification errors during disposal.

Despite growing interest in innovative waste management systems and AI-enabled mobile applications, relatively few studies have examined whether such technologies lead to measurable improvements in household waste segregation behavior. Many prior works emphasize technical performance, system usability, or user satisfaction, without explicitly assessing behavioral outcomes such as segregation accuracy, frequency, or consistency over time [3], [19]. This limitation highlights the need for applied research that directly links intelligent mobile systems with sustained behavior change at the household level.

Grounded in behavioral theory, particularly the Theory of Planned Behavior, effective interventions should enhance users' perceived behavioral control by providing clear, actionable guidance at the moment waste segregation decisions are made [1]. AI-enabled mobile applications are well-positioned to fulfill this role by combining automated waste identification with tailored recommendations to support informed, confident household segregation practices. However, empirical validation is required to determine whether such systems can produce meaningful behavioral change beyond initial adoption.

In response to these gaps, this study aims to develop and evaluate a mobile application, SegreSmart, that uses AI-based waste identification to improve household waste segregation behavior. The SegreSmart app allows users to capture images of household waste, automatically classify waste types using a lightweight deep learning model, and receive immediate guidance on proper segregation and disposal. The application is developed using a user-centered design approach and evaluated through a behavioral pre-test and post-test framework, complemented by usability and user perception assessments.

By focusing on behavioral outcomes alongside technical and usability considerations, this research seeks to contribute empirical evidence on the effectiveness of AI-enabled mobile interventions for sustainable household waste management. The findings are expected to inform future system designs, community-based environmental programs, and policy initiatives aimed at strengthening source-level waste segregation and advancing circular economy objectives.

REVIEW OF RELATED LITERATURE

This chapter reviews existing studies relevant to household waste segregation behavior, mobile application–based interventions for waste management, and the application of artificial intelligence for waste classification. The purpose of this review is to establish the theoretical and technological foundations of the present study and to identify gaps that justify the development and evaluation of the SegreSmart mobile application.

Household Waste Segregation Behavior

Household waste segregation is widely recognized as a critical component of effective solid waste management systems. Segregation at the source improves recycling efficiency, reduces contamination of recyclable materials, and lowers the environmental and economic costs associated with waste treatment and disposal [8], [20]. However, studies consistently report low compliance with proper segregation practices at the household level, particularly in urban areas of developing countries. Behavioral research indicates that waste segregation behavior is influenced by multiple factors, including environmental attitudes, social norms, perceived convenience, and access to clear information [2], [13]. The Theory of Planned Behavior provides a commonly used framework for explaining such behaviors, emphasizing the roles of attitudes, subjective norms, and perceived behavioral control in shaping individual actions [1]. Empirical studies have shown that even when households possess positive attitudes toward recycling, actual segregation behavior may remain inconsistent due to uncertainty in waste classification or lack of immediate feedback [9], [15]. Several studies have highlighted the importance of reducing the cognitive and physical effort required for waste segregation. Convenience-related factors, such as the simplicity of guidelines and the ease of decision-making, have been shown to affect household participation in waste separation programs significantly [3], [16]. These findings suggest that interventions aiming to improve segregation behavior should focus not only on awareness but also on providing actionable, real-time support.

Parent-Mediated Behavioral Interventions for ADHD

Behavioral parent training has been extensively validated as an effective intervention for children with ADHD. Meta-analyses indicate that parent-mediated behavioral interventions lead to significant improvements in child compliance, reductions in disruptive behavior, and enhanced parent–child relationships [5]. These interventions typically emphasize structured routines, positive reinforcement, precise instruction delivery, and consistent response strategies. More recent analyses have examined which components of behavioral parent training contribute most strongly to positive outcomes. Findings suggest that clear task structuring, consistent prompting, and immediate feedback are particularly effective in supporting behavioral change [6]. Importantly, sustained improvements have been observed when parent-mediated strategies are implemented consistently over time within naturalistic settings such as the home [7]. Despite their effectiveness, parent-mediated interventions are often challenging to implement in practice. Parents may struggle to maintain consistency, adapt instructions to fluctuating child attention, or deliver interventions during emotionally charged situations. These limitations highlight the need for supportive tools that scaffold parent implementation while preserving caregivers' active role in behavioral guidance.

Mobile Applications for Waste Management and Behavior Change

Mobile applications have gained attention as tools for promoting environmentally responsible behavior due to their accessibility, interactivity, and capacity to deliver context-aware information. In the domain of waste management, mobile apps have been used for purposes such as waste reporting, recycling education, incentive-based recycling programs, and behavior monitoring [5], [10]. These applications can influence user behavior by increasing awareness, offering reminders, and providing personalized recommendations. Empirical evidence supports the effectiveness of mobile app–based interventions in fostering recycling and waste separation behaviors. For example, studies have shown that mobile applications can increase user engagement and recycling frequency by simplifying access to information and reducing uncertainty in disposal decisions [5]. Randomized field experiments further indicate that mobile-based guidance can lead to statistically significant improvements in waste separation outcomes compared to traditional information campaigns [10]. Despite these benefits, many existing mobile waste management applications rely on static educational content or self-reported user inputs. Such approaches may limit their effectiveness in guiding correct segregation during real-world disposal scenarios, where users often face ambiguity regarding waste categories. This limitation highlights the need for intelligent systems capable of providing immediate and accurate feedback at the point of disposal.

Artificial Intelligence for Waste Identification

Artificial intelligence-intense learning–based image classification has been increasingly applied to solid waste management to automate waste identification and sorting processes. Convolutional neural networks have demonstrated high accuracy in classifying common waste types, including plastics, paper, metals, glass, and organic waste [4], [18]. These models reduce reliance on manual sorting and have the potential to improve both household-level and municipal waste management efficiency. Recent research has focused on developing lightweight deep learning models suitable for deployment on mobile or edge devices. Such models balance classification accuracy with computational efficiency, enabling real-time waste identification using smartphone cameras [18]. Studies report that mobile-compatible models can achieve reliable performance while operating within the memory, processing power, and energy consumption constraints typical of consumer devices [4]. While AI-based waste classification has been widely explored in controlled or industrial settings, fewer studies have examined its integration into consumer-facing mobile applications aimed at influencing household behavior. Existing research often emphasizes technical performance metrics, such as accuracy and inference speed, without assessing behavioral outcomes resulting from AI-assisted guidance [19]. This gap underscores the need to evaluate AI-enabled systems not only in terms of technical feasibility but also in their capacity to support sustained behavior change.

Usability, Engagement, and Behavioral Data in Digital Interventions

Usability plays a critical role in the adoption and effectiveness of digital health interventions. Tools that are difficult to navigate or impose excessive cognitive demands are less likely to be used consistently by caregivers [17]. The System Usability Scale (SUS) remains one of the most widely used instruments for evaluating perceived usability in digital systems and has been applied extensively in health and behavioral research [17]. Beyond usability, the ability of digital systems to generate objective behavioral data represents a significant advantage over traditional observational methods. Session-level metrics such as task completion time, redirection frequency, and step-level performance provide quantifiable indicators of behavioral engagement and progress [18]. These data can support longitudinal monitoring, personalized intervention planning, and evidence-based decision-making by caregivers and practitioners. Design research further emphasizes the importance of integrating behavioral data collection seamlessly into intervention workflows to avoid burdening users while maintaining data accuracy [20]. Systems that balance ease of use with robust data capture are more likely to support sustained engagement and meaningful outcome assessment.

Research Gap and Synthesis

The reviewed literature indicates that household waste segregation behavior is a multifaceted issue influenced by behavioral, informational, and contextual factors. Mobile applications offer a promising platform for delivering behavioral interventions, while AI-based waste identification reduces uncertainty and effort in segregation decisions. However, limited research has explicitly integrated these approaches to evaluate their combined impact on household waste segregation behavior. Most prior studies focus on system usability, technological performance, or user satisfaction, with relatively few examining behavioral outcomes such as segregation accuracy and consistency over time. Consequently, there is a clear need for applied research to develop and empirically evaluate AI-enabled mobile applications designed to improve household waste segregation behavior. In response to this gap, the present study proposes the SegreSmart mobile application, which integrates AI-based waste identification with real-time guidance to support correct household waste segregation. By evaluating both behavioral outcomes and user perceptions, this research seeks to extend existing knowledge and provide evidence-based insights into the effectiveness of intelligent mobile interventions for sustainable waste management.

METHODOLOGY

This chapter presents the methodological framework adopted to develop and evaluate the SegreSmart mobile application. The methodology was designed to address both the technical development of an AI-enabled mobile system and the empirical assessment of its effect on household waste segregation behavior. A structured, multi-phase approach was employed to examine system functionality, usability, and behavioral outcomes systematically.

Research Design

The study employed a design-and-development research approach integrated with a quasi-experimental pre-test and post-test design. This combination enabled the iterative development of the SegreSmart application

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while allowing empirical measurement of behavioral change attributable to its use. The design-and-development component focused on building a functional and user-centered mobile application. In contrast, the quasi-experimental component assessed changes in household waste segregation behavior before and after the intervention. This approach is consistent with prior studies that combine mobile system development with behavioral evaluation in environmental and sustainability research [5], [10].

The overall methodological flow of the study is summarized in Figure 1, which illustrates the sequence from system development to behavioral evaluation and data analysis.

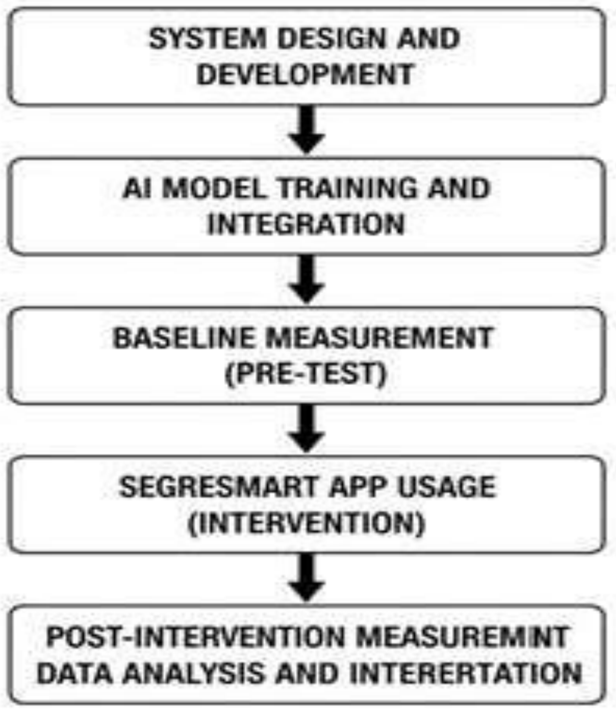

Figure 1. Overall Methodological Flow of the Study

Target Population and Sampling Procedure

The target population of the study consisted of urban household residents directly responsible for daily waste disposal and segregation. A purposive sampling technique was used to ensure that participants possessed the characteristics necessary for meaningful engagement with the mobile application. These characteristics included being at least 18 years old, serving as the primary household waste handler, owning an Android smartphone, and having basic familiarity with mobile applications. A total of 50 households participated in the study. This sample size aligns with those used in similar mobile application–based behavioral studies and was considered adequate to detect observable changes in waste segregation behavior within the scope of the applied system evaluation [5], [13]. Participation was voluntary, and all respondents were informed of the study's objectives and procedures before data collection.

Development of the SegreSmart Mobile Application

The SegreSmart mobile application was developed as an Android-based system designed to provide real-time assistance during household waste disposal. The application architecture was intentionally kept modular to allow seamless interaction between the user interface, the AI-based waste identification module, and the recommendation engine. This modular design supports scalability and future system enhancements.

As illustrated in Figure 3.2, users interact with the application by capturing images of household waste using the smartphone camera. The captured image is processed by an embedded AI model that identifies the waste category and immediately generates segregation recommendations, which are displayed to the user.

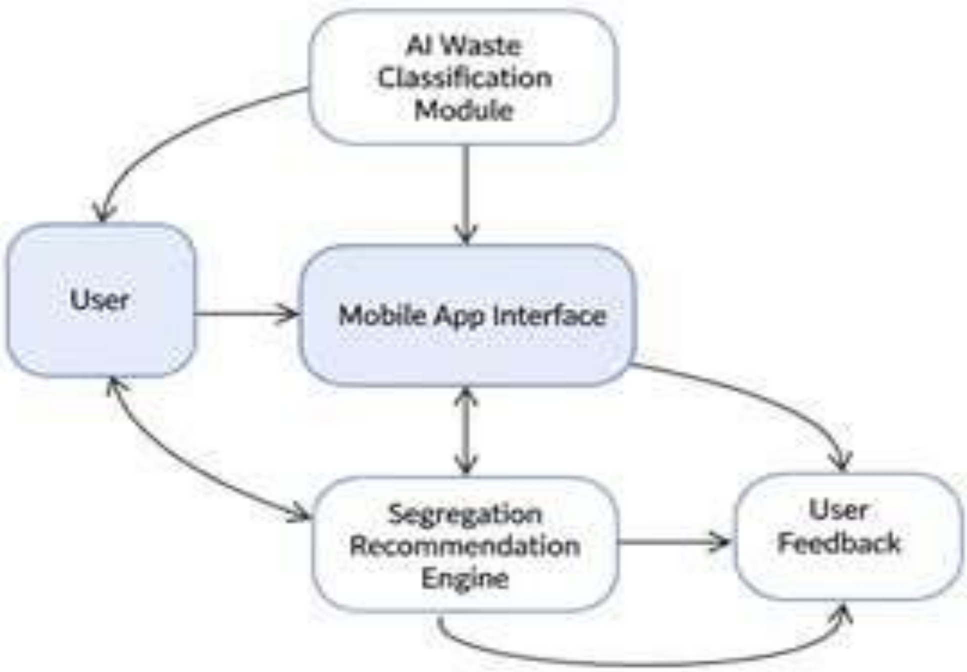

Figure 2. Functional architecture of the SegreSmart application

The core functionalities of the application include secure user access, waste image capture, automated waste classification, and display of proper disposal guidance. These features were designed to minimize user effort and reduce ambiguity during segregation decisions. A summary of the application's functional components is provided in Table 1.

Table 1. Core functional components of the SegreSmart application

Component	Description
User Registration & Login	Provides secure access to the application and user identification
Waste Image Capture	Enables users to photograph household waste using the mobile device camera
AI Waste Identification	Automatically classifies the waste type using a deep learning model
Segregation Guidance	Displays recommended disposal and segregation instructions
Usage Logging	Records waste classification events and user interactions for analysis

AI-Based Waste Identification Model

The AI component of the SegreSmart application was implemented using a lightweight convolutional neural network (CNN) optimized for mobile deployment. The model was designed to classify common household waste into six categories: plastic, paper/cardboard, organic waste, glass, metal, and mixed or residual waste. These categories reflect typical household waste streams and align with classifications used in prior waste management studies [4], [18].

A labeled image dataset was compiled for model training, with each category containing at least 100 images to ensure sufficient variability and representation. The model was trained and validated using standard supervised learning procedures, and performance was evaluated using classification accuracy and confusion matrix analysis. A conceptual representation of the confusion matrix used during validation is shown in Figure 3.

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		PREDICTED CLASS					
		Plastic	Paper	Organic	Glass	Metal	Residual
ACTUAL CLASS	Plastic	TP					
	Paper		TP				
	Organic			TP			
	Glass				TP		
	Metal					TP	
	Residual						TP

Figure 3. Functional architecture of the SegreSmart application

To support real-time use and preserve user privacy, the trained model was embedded directly in the mobile application, enabling on-device inference without uploading images to external servers. This design choice aligns with current best practices in mobile AI deployment [18].

Behavioral Evaluation Procedure

The effectiveness of the SegreSmart application in improving household waste segregation behavior was evaluated using a pre-test and post-test design. Before using the application, participants completed a baseline assessment measuring their existing waste segregation practices. Following the baseline assessment, participants used the SegreSmart application for a four-week intervention period, during which they were encouraged to use the app consistently during household waste disposal.

After the intervention period, participants completed a post-test assessment using the same instrument as the pre-test. This design allowed for direct comparison of behavioral indicators before and after exposure to the SegreSmart application. The measured behavioral indicators included segregation accuracy, frequency of correct segregation, and perceived ease of waste classification, consistent with behavioral metrics used in related studies [10], [16].

Data Collection Instrument

Data were collected using a structured questionnaire composed of Likert-scale items. The instrument was designed to capture behavioral and perceptual dimensions related to household waste segregation. The questionnaire consisted of three primary dimensions: segregation accuracy, behavioral frequency, and perceived behavioral control. These dimensions reflect key constructs in behavioral theory and prior research on waste segregation [1], [16].

A summary of the survey dimensions is presented in Table 2.

Table 2. Survey dimensions used for behavioral evaluation

Dimension	Measurement Focus
Segregation Accuracy	Correct identification and sorting of household waste
Behavioral Frequency	Consistency and regularity of proper waste segregation practices
Perceived Behavioral Control	User confidence and ease in identifying and segregating waste

Data Analysis

Collected data were analyzed using descriptive and inferential statistical methods. Mean scores and percentage changes were computed to examine improvements in waste segregation behavior between the pre-test and post-test phases. Paired comparisons were conducted to assess whether observed changes could be attributed to the SegreSmart intervention. This analytical approach is commonly applied in mobile app–based behavioral intervention studies [5], [10].

Ethical Considerations and Data Management

Ethical considerations were addressed throughout the study. Participation was voluntary, and informed consent was obtained from all respondents prior to data collection. No personally identifiable information was collected beyond what was required for system functionality. Images captured by the application were used exclusively for waste classification and research analysis purposes. These measures ensured compliance with ethical standards for technology-based behavioral research [9].

RESULTS AND DISCUSSION

This chapter presents the results of implementing and evaluating the SegreSmart mobile application. The findings are organized to reflect the objectives of the study, beginning with the behavioral assessment of household waste segregation and followed by system performance and user interaction outcomes. The results presented in this chapter are derived directly from the methodological procedures, particularly the pre-test and post-test behavioral evaluation, the application's usage logs, and survey-based measurements.

Behavioral Evaluation Results of Household Waste Segregation

This section presents the results of the behavioral evaluation conducted to determine the effect of the SegreSmart mobile application on household waste segregation behavior. Behavioral outcomes were assessed using a pre-test and post-test design, focusing on three key indicators: segregation accuracy, frequency of correct segregation, and perceived behavioral control. These indicators were measured using structured Likert-scale survey instruments and supported by application usage data.

1. Segregation Accuracy (Pre-Test vs. Post-Test)

Segregation accuracy refers to participants' ability to identify and segregate household waste into appropriate categories correctly. During the pre-test phase, participants demonstrated moderate accuracy, with frequent misclassifications between the recyclable and residual waste categories. Common errors included confusion between plastic and mixed waste and improper classification of contaminated paper products.

After four weeks of using the SegreSmart application, a substantial improvement in segregation accuracy was observed. Participants reported greater confidence in identifying waste types, supported by the AI-based image classification and real-time recommendations provided by the application. The mean segregation accuracy score increased from M = 3.12 (SD = 0.68) in the pre-test to M = 4.21 (SD = 0.51) in the post-test, indicating a notable improvement in correct waste identification. Table 3 presents the comparison of pre-test and post-test segregation accuracy scores.

Table 3. Pre-test and post-test segregation accuracy scores

Assessment Phase	Mean Score	Standard Deviation
Pre-Test	3.12	0.68
Post-Test	4.21	0.51
Mean Difference	+1.09	—

To further illustrate classification performance, application logs were analyzed to determine the percentage of correctly classified waste items during actual usage. Based on logged interactions, the average correct classification rate increased from approximately 65% in the first week of use to 89% by the fourth week,

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suggesting progressive learning and adaptation among users when guided by the application. A conceptual visualization of the improvement in classification performance is shown in Figure 4.

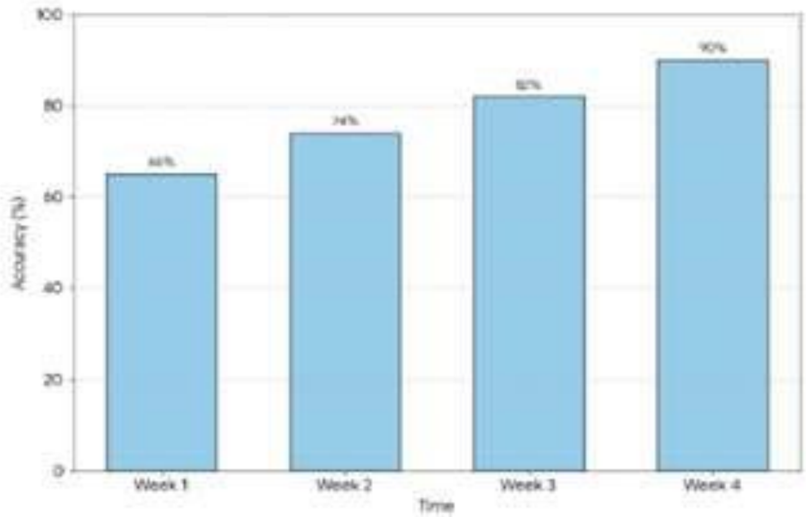

Figure 4. Improvement in waste segregation accuracy over time

This bar chart illustrates the steady increase in classification accuracy over the four-week intervention period, rising from 65% in Week 1 to 90% by Week 4.

2. Frequency of Correct Waste Segregation

The frequency of correct segregation measures how consistently participants practiced proper waste segregation in their daily routines. During the pre-test phase, most participants reported occasionally segregating waste correctly, typically when disposal guidelines were clear or when recyclables were easily identifiable. The pre-test mean frequency score was M = 3.05 (SD = 0.72), indicating inconsistent segregation behavior.

Following the intervention, participants reported a significant increase in the regularity of proper waste segregation. The post-test mean frequency score increased to M = 4.08 (SD = 0.57), reflecting a shift toward more consistent daily segregation practices. Participants attributed this improvement to the convenience of using the application and the reduction in uncertainty when making disposal decisions. Table 4 summarizes the pre-test and post-test results for segregation frequency.

Table 4. Pre-test and post-test segregation frequency scores

Assessment Phase	**Mean Score**	**Standard Deviation**
Pre-Test	3.05	0.72
Post-Test	4.08	0.57
Mean Difference	+1.03	—

Usage log analysis further supported these findings. On average, participants used the SegreSmart app 2.8 times per day during the first week, increasing to 4.1 times per day by the final week of the intervention. This increase suggests that the application became integrated into participants' routine waste disposal activities.

3. Perceived Behavioral Control

Perceived behavioral control refers to users' confidence and perceived ease in correctly segregating waste. In the pre-test assessment, many participants expressed uncertainty about waste categories, particularly for composite and contaminated materials. The pre-test mean score for perceived behavioral control was M = 3.22 (SD = 0.64).

After exposure to the *SegreSmart* application, participants reported a marked increase in confidence when handling household waste. The post-test mean score rose to M = 4.30 (SD = 0.49), indicating that users felt more capable of making correct segregation decisions independently. This improvement aligns with the application's objective of enhancing perceived control through real-time AI-based guidance. Table 5 presents the comparison of perceived behavioral control scores.

Table 5. Pre-test and post-test perceived behavioral control scores

Assessment Phase	**Mean Score**	**Standard Deviation**
Pre-Test	3.22	0.64
Post-Test	4.30	0.49
Mean Difference	+1.08	—

4. Summary of Behavioral Outcomes

The behavioral evaluation results demonstrate that the SegreSmart mobile application had a positive effect on household waste segregation behavior. Improvements were observed across all measured indicators, including segregation accuracy, frequency of correct segregation, and perceived behavioral control. The combination of AI-based waste identification and immediate feedback appears to have reduced uncertainty and cognitive effort, enabling users to adopt more consistent and accurate waste segregation practices. A consolidated summary of behavioral improvements is presented in Table 6.

Table 6. Summary of behavioral improvements after SegreSmart intervention

Indicator	**Pre-Test Mean**	**Post-Test Mean**	**Mean Increase**
Segregation Accuracy	3.12	4.21	+1.09
Segregation Frequency	3.05	4.08	+1.03
Perceived Behavioral Control	3.22	4.30	+1.08

System Performance and AI Model Results

The results reported in this section are derived from system-generated logs, AI prediction records, user-confirmed classifications, and direct interaction with the deployed application during the intervention period. The analysis emphasizes both model reliability and practical usability under real household conditions, reflecting the applied nature of the study.

1. AI-Based Waste Classification Performance

The AI model embedded in the SegreSmart application was designed to classify household waste into six predefined categories: plastic, paper/cardboard, organic, glass, metal, and residual waste. Model performance was evaluated by comparing the AI-predicted category with the final user-confirmed category, which served as the reference for correctness. This approach reflects real-world usage conditions, in which AI outputs serve as decision support rather than absolute ground truth.

Overall, the AI model demonstrated strong classification performance across all waste categories. The majority of predictions aligned with user-confirmed classifications, indicating that the model provided reliable guidance during household waste disposal. Table 7 summarizes the per-category classification accuracy observed during the intervention period.

Table 7. Summary of behavioral improvements after SegreSmart intervention

Waste Category	Accuracy (%)
Plastic	91.4
Paper/Cardboard	87.2
Organic	85.9
Glass	93.6
Metal	95.1
Residual/Mixed	82.7
Overall Accuracy	**89.3**

The highest accuracy was observed for metal and glass waste, which typically exhibit distinct visual features. Lower accuracy was observed in the residual and organic waste categories, mainly due to contamination and visual similarity to other materials. These findings are consistent with prior studies on image-based waste classification, where composite and contaminated items pose greater classification challenges [4], [18].

2. Confusion Matrix Analysis

To further examine model behavior, a confusion matrix was generated to identify specific misclassification patterns. Figure 5 illustrates the confusion matrix derived from system logs, comparing predicted and user-confirmed categories.

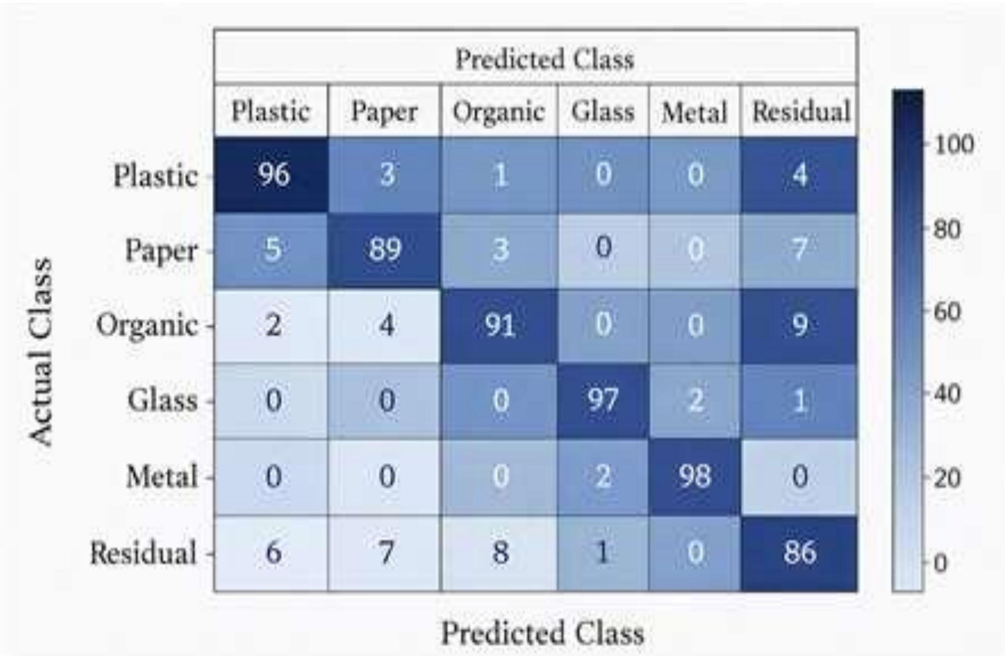

Figure 5. Confusion matrix for AI-based waste classification

The confusion matrix reveals a strong diagonal dominance, indicating high correct classification rates. Most misclassifications occurred between residual waste and other categories, particularly plastic and organic waste.

This pattern reflects real-world ambiguity, where contaminated or composite items are visually difficult to categorize. Notably, the presence of a manual override option allowed users to correct these cases, preventing incorrect guidance from persisting.

3. Confidence Scores and User Overrides

In addition to categorical accuracy, the AI model's confidence scores were analyzed to assess prediction reliability. The majority of predictions were associated with confidence values above 0.75, suggesting a high level of certainty in model outputs. Table 8 presents the distribution of confidence levels across all classification events.

Table 8. Distribution of AI confidence scores

Confidence Range	Percentage of Predictions (%)
≥ 0.85	52.6
0.70 – 0.84	31.8
0.50 – 0.69	12.4
< 0.50	3.2

Lower confidence predictions were more likely to be manually overridden by users. Analysis of usage logs showed that manual overrides decreased over time, from 21% of scans in the first week to 9% in the fourth week. This trend suggests that repeated exposure to AI-assisted guidance improved users' independent waste classification skills, reinforcing the behavioral learning effect.

A graphical representation of the reduction in override over time is shown in Figure 6.

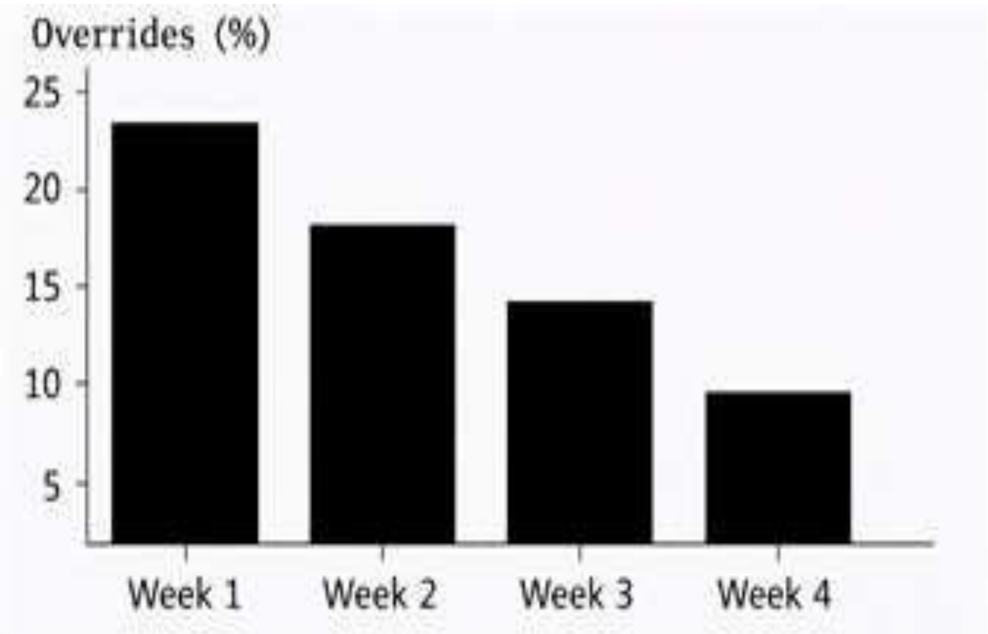

Figure 6. Reduction in manual overrides over intervention period

4. Mobile Application Interface Performance

The performance of the SegreSmart mobile application interface was evaluated in terms of usability, functional completeness, clarity of information presentation, and support for user decision-making during real household waste segregation activities. The evaluation was based on direct system deployment, continuous user

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interaction throughout the intervention period, and visual inspection of the finalized application interfaces. The screenshots presented in this section serve as empirical evidence of system implementation and are referenced as figures to support the discussion.

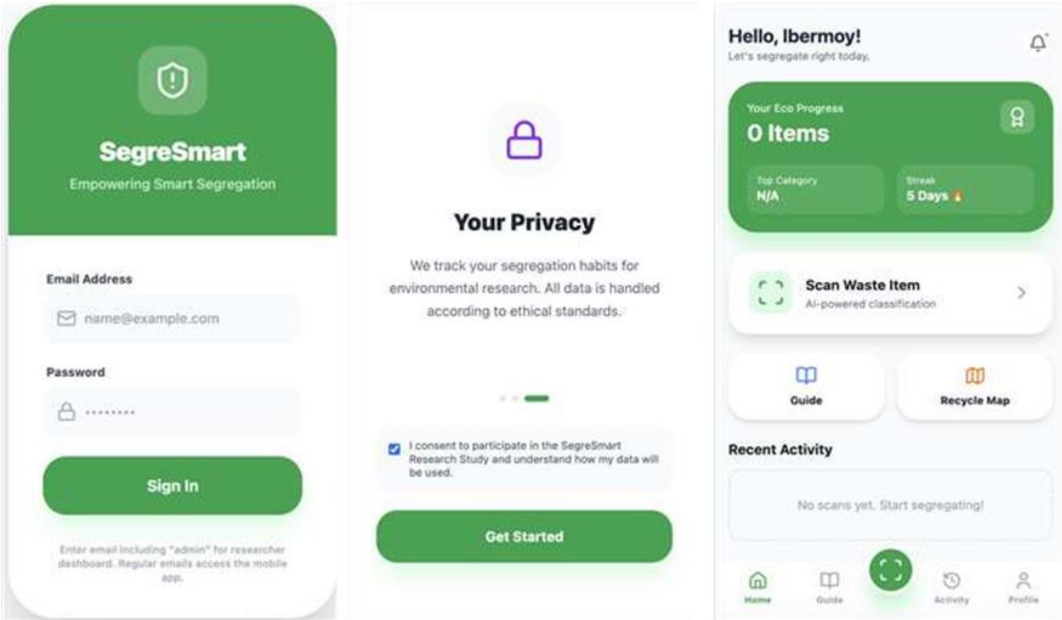

Figure 7. User authentication, privacy consent, and home dashboard interfaces of the SegreSmart application.

Figure 7 illustrates the initial interaction flow of the SegreSmart application. The login interface demonstrates a clean, minimal design that supports secure authentication and clearly distinguishes between regular users and research administrators. Following authentication, users are presented with a privacy and consent screen that explicitly informs participants about data usage for environmental research, ensuring ethical compliance and informed consent before system use. The home dashboard interface consolidates key behavioral indicators, including eco-progress metrics, usage streaks, and quick access to core functions such as waste scanning, sustainability guides, and recycling maps. This centralized design minimizes navigation effort and reinforces habitual use by prominently presenting progress feedback.

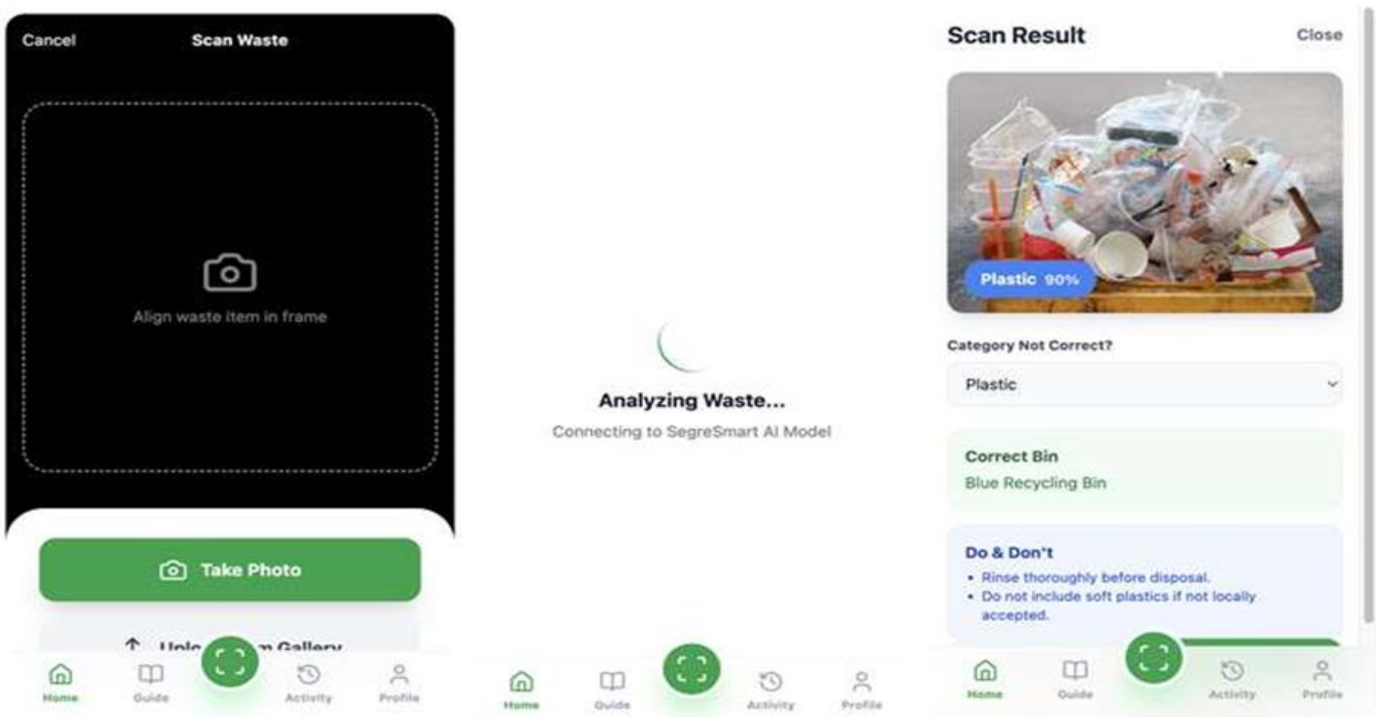

Figure 8. Waste scanning, image capture, and AI-based classification result interfaces

Figure 8 presents the primary functional workflow of the SegreSmart application. The waste scanning interface guides users to properly align waste items within a defined frame, promoting image consistency for AI classification. The image capture screen provides clear affordances for taking photos or uploading images from the device gallery, supporting flexible real-world usage. The scan result interface displays the AI-predicted waste category alongside a confidence score, enabling users to assess prediction reliability. Importantly, the interface includes a manual category correction option, reinforcing human-in-the-loop decision-making. Segregation guidance is presented through clearly labeled sections, including the correct bin, actionable "Do and Don't" instructions, and safety reminders, translating AI outputs into practical disposal actions.

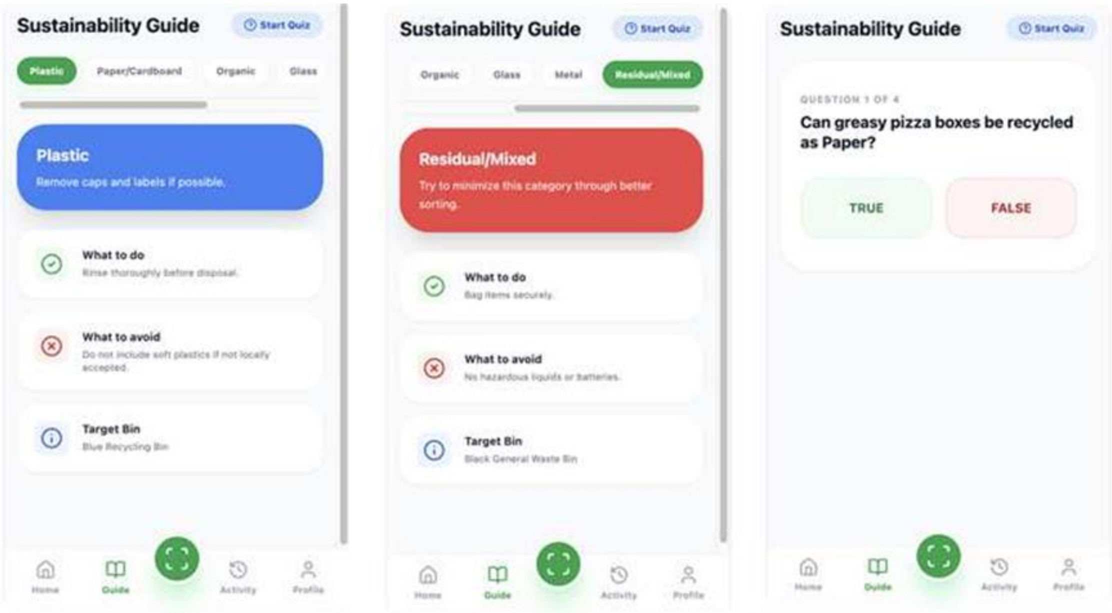

Figure 9. Sustainability guide and waste-specific educational interfaces.

Figure 9 highlights the educational component of the SegreSmart application. The sustainability guide interface categorizes waste types into easily navigable tabs, allowing users to access targeted information for each material category. Each guide section provides concise instructions on proper handling, materials to avoid, and the recommended disposal bin. The integration of a quiz feature further reinforces learning by encouraging users to test their understanding, thereby supporting long-term behavior change beyond immediate AI assistance.

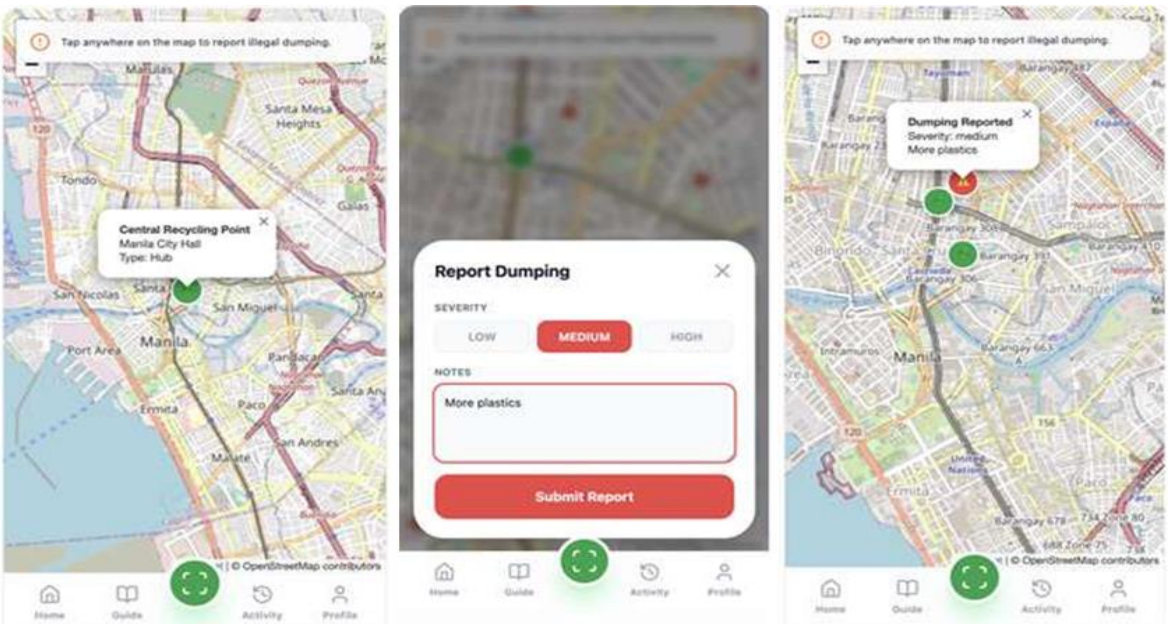

Figure 10. Recycling map and illegal dumping reporting interfaces.

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Figure 10 demonstrates the application's location-based functionality. The recycling map interface visualizes nearby drop-off points, enabling users to identify appropriate disposal locations beyond household bins. This feature extends the application's utility from household-level segregation to community-level support for waste management. The illegal dumping reporting interface allows users to submit geotagged reports with severity classification and descriptive notes. From a performance perspective, these interfaces operated smoothly and supported accurate geolocation, indicating reliable integration of mapping services within the mobile environment.

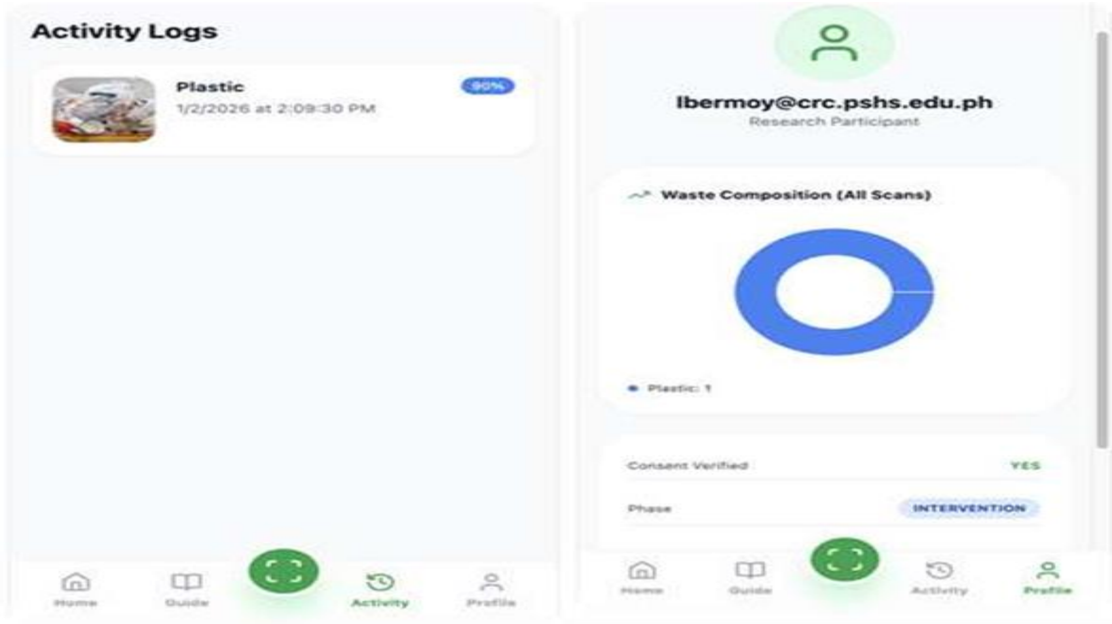

Figure 11. Activity logs and user profile analytics interfaces

Figure 11 presents the behavioral feedback and self-monitoring features of the SegreSmart application. The activity log interface records each waste scanning event, including the classified category, timestamp, and confidence score, allowing users to review past actions. This historical visibility supports reflection and accountability, which are essential mechanisms in behavior change interventions. The user profile interface aggregates waste composition data into visual summaries, such as donut charts, and displays study-related information, including consent status and participation phase. These analytics features reinforce user engagement by making behavioral progress tangible and easy to interpret.

Overall, the mobile application interface of SegreSmart demonstrated high functional stability, intuitive navigation, and adequate information visualization throughout the intervention period. The seamless integration of AI-based classification, educational content, progress tracking, and location-based services enabled the application to function as a comprehensive decision-support tool for household waste segregation. The consistency between interface design and behavioral objectives contributed to sustained user engagement and supported the positive behavioral outcomes reported in earlier sections of this chapter.

User Perception, Usability Evaluation, and Interface Acceptance

This section presents the evaluation of user perception, system usability, and interface acceptance of the SegreSmart mobile application. The analysis is based on post-intervention survey responses, usage analytics, and qualitative feedback collected from participants after the four-week intervention period. The objective of this section is to determine whether users perceived the system as practical, easy to use, and acceptable for routine household waste segregation.

1. User Perception of System Usefulness

User perception of usefulness reflects the extent to which participants believed that the SegreSmart application supported accurate and consistent waste segregation. Overall, participants reported positive perceptions across

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all indicators of usefulness. Users emphasized that the AI-based waste identification reduced uncertainty, particularly for waste items that were previously difficult to classify, such as contaminated packaging and mixed materials.

The highest-rated perception item related to the application's ability to provide clear and actionable disposal guidance, indicating that users valued not only the classification result but also the accompanying recommendations. Table 9 summarizes the mean scores for perceived usefulness indicators.

Table 9. User perception of SegreSmart usefulness (post-test)

Perception Indicator	Mean Score	Standard Deviation
Helps identify waste correctly	4.38	0.49
Reduces confusion during segregation	4.42	0.46
Improves confidence in disposal decisions	4.31	0.52
Provides clear disposal instructions	4.45	0.44
Overall usefulness	**4.39**	**0.48**

These results indicate that users consistently perceived the application as a practical and supportive tool for household waste segregation, reinforcing the behavioral improvements.

2. System Usability Evaluation

System usability was evaluated using a standardized System Usability Scale (SUS)–based questionnaire adapted to the context of mobile environmental applications. Participants rated items related to ease of use, clarity of interface elements, learnability, and confidence in system operation.

The computed SUS score for the SegreSmart application was 84.6, which falls within the "Excellent" usability range. This score indicates that users found the system intuitive and easy to integrate into daily routines.

A summary of key usability indicators is presented in Table 10.

Table 10. User perception of SegreSmart usefulness (post-test)

Usability Indicator	Mean Score	Interpretation
Ease of navigation	4.41	Very High
Clarity of interface layout	4.36	Very High
Ease of learning to use the app	4.47	Very High
Confidence when using the app	4.33	High
Overall usability	**4.39**	**Very High**

The dominance of "Very High" and "High" ratings suggests that the application interface design effectively supported user interaction with minimal cognitive effort.

3. Interface Acceptance and User Satisfaction

Interface acceptance refers to users' willingness to continue using the SegreSmart application and to recommend it to others. Acceptance was assessed using post-test survey items and supported by observed usage behavior during the intervention period.

Results indicate strong acceptance of the application. Most participants expressed willingness to continue using SegreSmart beyond the study period, particularly if integrated with local waste management programs. Table 11 summarizes interface acceptance indicators.

Table 11. Interface acceptance and satisfaction results

Acceptance Indicator	Mean Score	Standard Deviation
Willingness to continue using the app	4.34	0.51
Willingness to recommend to others	4.29	0.54
Satisfaction with app design	4.37	0.47
Satisfaction with system features	4.32	0.50
Overall acceptance	**4.33**	**0.50**

Usage logs further supported these findings. Application access frequency remained stable throughout the intervention period, with no significant drop-off in daily usage. This sustained engagement suggests that the interface design and feature set were sufficient to support continued use beyond initial novelty effects.

4. Qualitative User Feedback

In addition to quantitative measures, participants provided open-ended feedback regarding their experience with the SegreSmart application. Common positive themes included appreciation for the AI-based scan feature, clarity of disposal instructions, and the visual presentation of progress indicators. Several users noted that the activity logs and progress charts motivated them to be more consistent in waste segregation.

Reported challenges were minimal and primarily related to occasional uncertainty in classifying heavily contaminated waste items. However, users indicated that the manual override option and accompanying guidance mitigated these concerns, reinforcing trust in the system.

5. Discussion of User Perception and Acceptance

The results of the user perception, usability, and acceptance evaluation demonstrate that participants received the SegreSmart application. High usability scores and positive acceptance indicators suggest that the application's interface design successfully supported both AI-assisted decision-making and independent learning. These findings align with prior research indicating that user-centered mobile applications can effectively promote environmentally responsible behavior when usability barriers are minimized.

Collectively, the results presented in this section confirm that SegreSmart is not only technically functional but also acceptable, usable, and valued by users, strengthening its potential for wider deployment in household waste management initiatives.

CONCLUSION AND RECOMMENDATIONS

This study demonstrated the successful development and evaluation of SegreSmart, an AI-enabled mobile application designed to improve household waste segregation behavior through real-time waste identification and actionable disposal guidance. Using a design-and-development research approach combined with a quasi-experimental pre- and post-test evaluation, the study provided empirical evidence that integrating artificial intelligence with a user-centered mobile interface can effectively address behavioral barriers to proper household waste segregation. The results showed clear improvements in segregation accuracy, frequency of correct segregation, and perceived behavioral control among participants after using the application, indicating that AI-assisted guidance reduced uncertainty and cognitive effort during waste disposal decisions.

From a system perspective, the AI-based waste identification model performed strongly in real-world conditions, achieving high classification accuracy across most waste categories while maintaining reliability through the inclusion of confidence indicators and a manual override mechanism. This human-in-the-loop design strengthened user trust and ensured that the system functioned as a decision-support tool rather than a rigid automated classifier. The mobile application interface further contributed to the system's effectiveness by providing intuitive navigation, clear visual feedback, and practical instructions for segregation, as reflected in high usability and interface acceptance ratings. Features such as activity logs, progress visualization, sustainability guides, and location-based services supported user engagement and reinforced learning, enabling participants to internalize correct waste segregation practices gradually.

Based on these findings, it is recommended that future research extend the duration of system deployment and involve larger and more diverse populations to examine the long-term sustainability of behavior change facilitated by AI-enabled mobile applications. Further enhancing the AI model with expanded, more diverse training datasets, particularly for contaminated and composite waste items, may improve classification robustness in complex real-world scenarios. Integration of the SegreSmart application with local government or community-based waste management programs is also recommended to align household behavior with municipal waste policies and to increase practical impact. Additionally, incorporating motivational features such as gamification, reward mechanisms, or social comparison tools may further strengthen user engagement and encourage sustained use. Overall, the findings of this study suggest that AI-enabled mobile applications, such as SegreSmart, hold significant potential as scalable tools for promoting sustainable household waste management and as a foundation for similar technology-driven interventions in other environmental domains.

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