A USER CENTERED DESIGN (UCD) OF A MOBILE APP ENCOURAGING PROPER DISPOSAL OF RECYCLABLE PRODUCTS

BY

VICTOR CHIBUNDU EZEANI

PSC2105333

A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE, FACULTY OF PHYSICAL SCIENCES, UNIVERSITY OF BENIN, BENIN CITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A BACHELOR OF SCIENCE (B.Sc.) DEGREE IN COMPUTER SCIENCE

NOVEMBER 2025

CERTIFICATION

This is to certify that this project work was carried out by **VICTOR EZEANI CHIBUNDU** with Matriculation Number **PSC2105333** under my supervision. It is adequate and satisfactory, both in scope and content, for the award of Bachelor of Science (B.sc) Degree in Computer Science of the University of Benin

PROF. (MRS.) V. V. N. AKWUKWUMA
Project Supervisor

DATE

APPROVAL

This project work is hereby approved in partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc.) Degree in Computer Science from the University of Benin.

DR. (MRS.) A.R. USIOBAIFO
Head of Department

DATE

DEDICATION

This project is dedicated to God Almighty for giving me the strength and wisdom to see it through to completion, and even throughout my stay in the University of Benin (UNIBEN). It is also dedicated to my parents; Mr and Mrs Ezeani and my family; for their love, support and guidance throughout my academic journey.

ACKNOWLEDGEMENT

My greatest acknowledgement goes to God Almighty for giving me the strength, wisdom and direction throughout my academic journey. I would like to express my gratitude to my project supervisor, who is also the Dean of the Faculty of Computing, Prof. (Mrs.) V.V.N. Akwukwuma, for her consistent guidance towards ensuring the successful completion of this project.

I would also like to specially thank my project coordinator Dr. Osagie Maxwell, and other lecturers in the Department of Computer Science who I have been opportune to cross paths with, and have impacted me immensely these past few years: Dr. (Mrs.) A.R. Usiobaifo, Prof. G.O. Ekuobase, Prof. F.I. Amadin, Prof. (Mrs.) S. Konyeha, Prof. (Mrs.) V.I. Osubor, Mr. D.N. Idehen, Mr. P. E.B. Imiefoh, Dr. (Mrs.) Aziken, Dr. F.O. Chete, Dr. (Mrs) R.O. Osaseri, Dr. F. O. Oliha, Dr. J.C. Obi, Mr. I.E. Obasohan, Mr. S.O.P. Oliomogbe, Mr. K.O. Otokiti, Mr. I.E. Obayagbona, Mrs. R.I. Izevbizua, Mr. E.C. Igodan, Miss L.O.Usiosefe, Mr J. Okhuoya, Prof. F.A.U. Imouokhome, Mrs. J.I. Adun and Dr. E. Nweli.

Finally, I also want to appreciate those who contributed to the success of this project: Emman uel Oshike, Mukarama Abdulsalami, Tomison Thomas and Goodness Chinede. I would also like to thank my family and friends for their support, words of encouragement, and consistent guidance throughout this project.

TABLE OF CONTENT

CERTIFICATION.....**i**

APPROVAL.....**ii**

DEDICATION.....**iii**

ACKNOWLEDGEMENT.....**iv**

TABLE OF CONTENT.....**v**

LIST OF TABLES.....**v**

LIST OF FIGURES.....**vi**

ABSTRACT.....**vii**

INTRODUCTION.....**1**

1.1 Introduction.....1

1.2 Statement of the Problem.....2

1.3 Aim and Objectives of the Study.....2

1.4 Significance of the Study.....3

1.5 Scope of the Study.....3

1.6 Definition of Terms.....4

CHAPTER 2.....**5**

2.1 Introduction.....5

2.2 Theoretical Foundations: Mobile Technology and Pro-Environmental Behavior.....6

2.3 Core Principles of UI/UX Design for Recycling Applications.....7

2.3.1 Enhancing Usability and Accessibility.....7

2.3.2 Fostering Engagement and Sustained Motivation.....7

2.3.3 Building Trust Through Information and Feedback.....8

2.4 Empirical Review of Mobile Recycling Interventions.....8

2.5 The Nigerian Context.....10

2.6 Synthesis and Identification of the Research Gap.....11

CHAPTER 3.....**13**

METHODOLOGY.....**13**

3.1 Research Methodology.....13

3.1.1 Application of the Design Thinking Model..... 13
3.2 Analysis of Existing Systems..... 14
3.2.1 Digital Recycling Applications..... 14
3.2.2 Existing Physical System (University of Benin)..... 14
3.3 Problem Definition (Findings from the "Empathize" Phase)..... 15
3.4 Overview of the Proposed System ("UNICYCLE")..... 15
3.5 Application Flow Diagram..... 16
3.6 Data Collection and Evaluation Methods..... 18
3.7 Ethical Considerations..... 19
CHAPTER 4..... 20
IMPLEMENTATION..... 20
4.1 Introduction..... 20
4.2 Tools and Technologies..... 20
4.3 The "UNICYCLE" High-Fidelity Prototype (First Iteration)..... 20
4.3.1 Onboarding and User Authentication..... 20
4.3.3 Core Educational Modules..... 23
4.3.6 Session Management..... 26
4.4 Design Rationale and UI/UX Principles in Practice..... 27
4.4.1 Color Palette and Branding..... 27
4.4.2 Interactive Feedback and System Visibility..... 27
4.4.3 Leveraging User Familiarity for Feedback..... 28
4.5 Second Iteration: Design Refinement Based on User Feedback..... 28
4.5.1 Enhanced Onboarding and Authentication..... 29
4.5.4 Introduction of Interactive Sorting and Impact Tracking..... 34
4.6 The System Usability Scale (SUS) as an Evaluation Tool..... 36
CHAPTER 5..... 41
SUMMARY..... 41
5.1 Summary of the Study..... 41
5.2 Recommendations for Future Work..... 42

5.3 Conclusion..42

LIST OF TABLES

Table 2.1 Summary Table of Related Works 9
Table 4.1 User's Usability Scores Table 38

LIST OF FIGURES

Figure 3.1 - Application interaction flow 17
Figure 4.3 - Onboarding Page 21
Figure 4.31 - The Homepage: The Central Hub 22
Figure 4.32 - Information on Recycling 23
Figure 4.33 - Benefits of Recycling 24
Figure 4.34 - How to Recycle 24
Figure 4.35 - Did you know? 25
Figure 4.36 - Quiz Section 25
Figure 4.37 - Location 26
Figure 4.5 - Revised Onboarding 29
Figure 4.51 - Revised Authentication flow 30
Figure 4.52 - Homepage 31
Figure 4.53 - Revised Log Out Confirmation 32
Figure 4.54 - Revised Information on Recycling 33
Figure 4.55 - Interactive Feedback 33
Figure 4.56 - Gamification Loop 34
Figure 4.57 - Bar Code Scanner 35
Figure 4.58 - Admin Authentication 35
Figure 4.59 - Bin Management 46

ABSTRACT

Sustainable waste management is one of the most important activities in any institution, as it directly influences environmental health and campus sustainability. So far, the manual methods adopted at the University of Benin (UNIBEN) have proven to be inadequate, extremely confusing for users, and lacking in motivation, amongst other disadvantages.

This project emphasizes the need to adopt a more modern, user-centered digital solution. These methods include mobile apps and other digital interventions. Taking into consideration the constraints and the scope of the project, which is the University of Benin, the method proposed by this project is a User-Centered mobile application named "UNICYCLE."

However, this project focuses on the UI/UX design and high-fidelity prototyping of this application, where the campus community can access educational guides, learn to sort waste, and be motivated through gamification. The system is validated by user feedback and quantitative testing.

This project makes use of the User-Centered Design (UCD) approach, specifically the five-phase Design Thinking model (Empathize, Define, Ideate, Prototype, Test), to represent the designs for the system architecture.

These designs served as the framework for the final prototype. The system can handle the whole process of promoting recycling behavior, from user education and motivation to providing real-time utility, validated by an "Excellent" System Usability Scale (SUS) score of 87.0.

CHAPTER 1

INTRODUCTION

1.1 Introduction

All over the world, cities and institutions are facing a growing problem: what to do with the massive amount of waste we produce every day. This issue, known as Municipal Solid Waste (MSW) management, has become a major environmental concern (Ali & Yusuf, 2023). As populations grow and lifestyles change, the challenge of managing this waste sustainably becomes more urgent. In many developing countries, including Nigeria, this problem is particularly severe due to limited infrastructure and resources.

Nigeria generates an estimated 32 million tons of solid waste annually (Bakare, 2020), but reports suggest that only 20-30% of this is collected and managed properly . The national recycling rate is extremely low, with some sources estimating it to be less than 15% for common materials like plastic , and other academic studies placing the figure at less than 12% (Babayemi et al., 2018; Yalwayi et al., 2024). This widespread ineffective waste management leads to serious environmental problems, such as blocked drainage systems which worsen flooding, and significant public health risks.

The University of Benin (UNIBEN) provides a clear example of this national challenge on a local scale. As a large and bustling academic community, the campus generates a substantial amount of waste, estimated at over 25,000 kg every day (Uwadiae et al., 2017). A significant portion of this waste consists of recyclable materials like plastics, rubber, and paper, which are currently not being effectively managed. In response to similar environmental challenges globally, there has been a growing interest in using digital technology, particularly mobile applications, to encourage pro-environmental behaviours like recycling. By applying principles of good User Interface (UI) and User Experience (UX) design, these applications can make recycling easier, more engaging, and more accessible for everyone (Aguiar-Castillo et al., 2018) .

1.2 Statement of the Problem

The core problem at the University of Benin is the lack of an effective and engaging system for managing recyclable waste at the source. Despite the large volume of recyclable materials generated daily by the campus community, there is no structured process to encourage or facilitate proper waste segregation. This leads to valuable materials ending up in open dumpsites, contributing to environmental pollution on campus.

Several factors contribute to this problem:

1. **Lack of Knowledge and Awareness:** Many in the community are not sufficiently informed about what can be recycled, how to sort different materials, or why it is important.
2. **Inconvenience:** The process of recycling is often seen as a "hassle." Without clear information on bin locations or collection schedules, users are less likely to participate (Bonino et al., 2016).
3. **Low Motivation:** There are currently few or no direct incentives or motivational drivers to encourage the community to adopt and maintain recycling habits, a key barrier that gamification and persuasive design seek to overcome (Aguiar-Castillo et al., 2018).

While mobile applications for recycling exist in other parts of the world, they are typically designed for different contexts with established recycling infrastructures and different user demographics. A solution designed for a general urban population in Europe or Asia may not be effective for the unique social dynamics, daily routines, and digital literacy levels of a Nigerian university campus. Therefore, there is a clear need for a solution that is specifically designed with the UNIBEN community in mind.

1.3 Aim and Objectives of the Study

The aim of this study is to design and develop a user-centered mobile application prototype that applies UI/UX principles to encourage and facilitate recycling behaviour among the University of Benin community.

To achieve this aim, the following objectives have been set:

1. To investigate the current waste management practices and recycling behaviours within the University of Benin.
2. To identify the key barriers and motivators for recycling within the UNIBEN community.
3. To apply User-Centered Design (UCD) principles to design a mobile application prototype with a focus on usability, accessibility, and engagement.
4. To develop a high-fidelity prototype of the disposal of the mobile application based on the design.
5. To evaluate the usability and potential effectiveness of the application prototype with representative users.

1.4 Significance of the Study

This research is significant for several reasons. Practically, it aims to provide a tangible solution to the pressing waste management problem at the University of Benin, which could lead to a cleaner and more sustainable campus environment. If successful, the developed application could serve as a model for other tertiary institutions across Nigeria facing similar challenges.

Academically, this study will contribute valuable insights to the field of Human-Computer Interaction (HCI) and sustainable design. It addresses a notable gap in the literature by focusing on a digital environmental intervention within a sub-Saharan African university context—an area that is currently under-researched, especially when compared to digital health interventions (Adewoyin et al., 2025) . The findings will provide a practical case study on how to apply UI/UX and UCD principles in an environment with unique infrastructural and socio-technical characteristics (Nkwo & Ede, 2020).

Furthermore, this project aligns with the University of Benin's institutional goals for environmental sustainability, as demonstrated by its involvement in initiatives such as the "Sustainable Plastic Waste and Recycling Management" (SWARM) project.

1.5 Scope of the Study

This study is focused on the design, development, and evaluation of a mobile application prototype. The geographical scope is limited to the Ugbowo Campus of the University of

Benin. The target population for user research and prototype testing will be the UNIBEN campus community, with a primary focus on the student body as the largest segment.

The technical scope of this project covers the UI/UX design process—from user research and requirements gathering to the creation of a high-fidelity, interactive prototype. It will not include the development of a fully functional, backend-integrated live application or the physical implementation of the waste collection logistics. The evaluation will be focused on the usability and user acceptance of the prototype, not its long-term impact on campus recycling rates.

1.6 Definition of Terms

- **Gamification:** The application of game-like elements, such as points, badges, and leaderboards, in a non-game context to increase user engagement and motivation.
- **Municipal Solid Waste (MSW):** Non-hazardous waste generated from residential, commercial, and institutional sources, such as households, offices, and schools.
- **Prototype:** A preliminary, interactive model of the mobile application that simulates its functionality and is used for testing and gathering feedback before full development.
- **Recycle:** Proper disposing of recyclable products in recycle bins.
- **User-Centered Design (UCD):** An iterative design approach that focuses on understanding the needs, goals, and limitations of users at every stage of the design process.
- **User Experience (UX):** This describes the overall experience and satisfaction a user has while interacting with the application, including how easy and enjoyable it is to use.
- **User Interface (UI):** This refers to the visual and interactive elements of the mobile application that a user interacts with, including screens, buttons, icons, and layout

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Waste management is a major topic for environmental research and policy around the world. As cities grow and people consume more, dealing with municipal solid waste (MSW) has become a serious problem. To solve this, researchers have been looking at how digital tools, especially mobile apps, can help encourage people to recycle. These apps use good user interface (UI) and user experience (UX) design to make recycling easier, provide information, and keep users motivated.

The University of Benin (UNIBEN) is a good example of the waste management problems in Nigeria. The campus community produces about 25,643.8 kg of waste every day, which puts a lot of pressure on the environment (Uwadiae et al., 2017). This is part of a larger national problem, as Nigeria's overall recycling rate is very low. For example, reports from BusinessDay suggest that less than 15% of plastic waste is recycled. This shows that we need effective solutions that are designed for our local situation. While recycling apps from other countries can give us good ideas, an app for UNIBEN must be designed based on the specific environmental, infrastructural, and digital conditions on campus.

Because Nigeria's national waste collection system is not very effective, with some sources like Punch Nigeria estimating that only 20-30% of all waste is properly collected, a campus-based app cannot just be about changing behaviour. It must also connect to a reliable collection system on campus. This review will look at the theories behind using mobile apps for pro-environmental behaviour, the main principles of UI/UX design for these apps, and examples from other countries. It will then focus on the Nigerian context and the specific situation at UNIBEN to identify the need for a custom-built mobile recycling app.

2.2 Theoretical Foundations: Mobile Technology and Pro-Environmental Behavior

To understand how a mobile app can change recycling habits, we can use established theories about human behaviour. The Theory of Planned Behavior (TPB), developed by Ajzen (1991), is a useful framework. TPB suggests that a person's intention to do something is the best

predictor of their actual behaviour. This intention is shaped by three main things: attitude toward the behavior, subjective norms, and perceived behavioral control. A well-designed mobile app can use its UI/UX features to influence each of these areas and encourage recycling.

Perceived Behavioral Control (PBC) is about how easy or difficult a person thinks it is to perform a behavior. Many people don't recycle because it seems like too much trouble. They might not know how to sort materials, where to find recycling bins, or when collection happens (Bonino et al., 2016). A mobile app can make these things easier. A simple UI with a guide on sorting, a map showing bin locations, and a pickup schedule can reduce the effort involved. By making recycling feel more manageable, the app helps users feel more confident that they can do it, which is an important step towards forming the intention to recycle.

Attitude is a person's positive or negative feeling about doing something. If recycling is seen as a boring chore, people will have a negative attitude towards it. UI/UX design can help change this. By adding game-like elements (gamification), such as points for recycling, leaderboards for competition, and rewards, an app can make the experience more fun. For example, the SISAKU app in Indonesia used a points system to motivate users (Soleh & Maukar, 2024). This approach can change a user's attitude from feeling obligated to feeling engaged and rewarded.

Subjective Norms refer to the social pressure a person feels to behave in a certain way. On a university campus like UNIBEN, what friends and classmates do is very influential. A recycling app can use this social dynamic. Features that let users form teams, share their achievements, or see their faculty's collective impact can create a sense of community. This makes recycling a more visible and socially accepted activity, encouraging more people to participate.

Knowledge is also very important. Many people don't recycle simply because they don't have enough information. A study by Purbo et al. (2024) found that 68% of users didn't sort their waste because they didn't know how. Research at the University of Benin has also shown that environmental education helps improve students' knowledge and attitudes about waste segregation (Ogunyemi et al., 2023). This means that for UNIBEN students, an app should first be an educational tool. By providing clear and relevant information—like what types of

plastics can be recycled on campus—the app can build the knowledge needed for students to develop positive attitudes and feel in control of their recycling habits.

2.3 Core Principles of UI/UX Design for Recycling Applications

For a recycling app to be effective for a diverse group like UNIBEN students, it must follow key UI/UX design principles. These principles help turn behavioral theories into a practical tool that people will actually use. The most important areas are usability and accessibility, engagement and motivation, and building trust through information and feedback.

2.3.1 Enhancing Usability and Accessibility

Usability is about how easy it is for someone to use an app to get things done. For a busy UNIBEN student, a recycling app must be simple and quick to use. This means it should have clear menus, a logical layout, and simple steps for tasks like scheduling a pickup or identifying a material (Purbo et al., 2024). The design should be clean and not overwhelm users with too many options.

Accessibility means the app should be usable by everyone, no matter their level of tech skills. This is very important in Nigeria, where digital literacy varies. Not everyone is an expert with technology, so an app designed for UNIBEN must not assume high digital skills. The design should use simple icons (like a recycling symbol), plain language, and a consistent layout so that it is easy for everyone to use (Aguiar-Castillo et al., 2018). For this project, making the app accessible is essential for it to be adopted widely.

2.3.2 Fostering Engagement and Sustained Motivation

While a usable app is good for getting people to download it, keeping them engaged is what leads to long-term success. Engagement is about how well an app holds a user's attention and makes them want to use it again. This can be achieved through motivation.

Gamification is a popular way to motivate users. As seen with the SISAKU app, features like points, badges, and leaderboards can make recycling feel like a fun game and encourage people to participate regularly (Soleh & Maukar, 2024). Another key factor is the app's performance. A study by Saptaputra et al. (2023) showed that a responsive app that works

quickly without lagging keeps users coming back. A UNIBEN student is more likely to use an app that is fast and reliable than one that is slow and frustrating.

2.3.3 Building Trust Through Information and Feedback

Trust is a user's belief that the app and the recycling system it represents are reliable. In a place like Nigeria, where people may not have much confidence in public services, building trust is crucial (Agbebaku, 2021). The app's UI/UX must be designed to be transparent and communicative.

A key principle in UX design is showing the "visibility of system status," which means the app should always let users know what is happening. For a recycling app, this means giving clear and immediate feedback. For example, when a user schedules a pickup, the app should immediately show a "Pickup Confirmed" message. When they earn points, the balance should update right away. This constant feedback builds confidence that the system is working and that their efforts are making a difference. Without this reassurance, users might quickly abandon the app, assuming it is not effective.

2.4 Empirical Review of Mobile Recycling Interventions

The design principles for changing behavior have been tested in different parts of the world. Looking at studies from Italy and Indonesia gives us useful lessons on what works and what doesn't. These studies show that putting the user at the center of the design process is key to creating successful recycling apps.

Bonino et al. (2016) developed the "WasteApp" in Turin, Italy, by working directly with citizens to design it. The app included features like a barcode scanner to identify materials and a map to find bins. Usability tests showed that while it was mostly successful, some users had trouble with certain tasks, which shows the need for careful testing. The study also noted that many other city waste apps had low download numbers because they were confusing or had outdated information, proving that good UI/UX is important.

In Kesugihan District, Indonesia, Purbo et al. (2024) used a method called Design Thinking to create a recycling app. This user-focused approach led to features that gave users real benefits, like requesting a pickup and getting money for their recyclables. The app was tested using the System Usability Scale (SUS), a standard tool to measure how easy an app is to use.

It received a "Good" score of 71, which was better than other local apps. This shows that combining an easy-to-use design with real rewards can increase user engagement.

Also in Indonesia, Soleh and Maukar (2024) developed the "SISAKU" app in Jakarta, also using Design Thinking. Their app included pickup scheduling, a points-based reward system, and a feature for reporting illegal dumping. The app was very successful, getting an excellent SUS score of 80.29. Usability tests also showed that users could complete tasks like scheduling a pickup with a high success rate (92%–100%). The success of SISAKU shows that a mix of convenience and motivation can lead to high user satisfaction.

Looking at these studies together (summarized in Table 2.1), we can see some common themes. The successful apps in Indonesia both used the Design Thinking method and included reward systems, which suggests that incentives are a strong motivator. The mixed results of WasteApp show that even when users are involved in the design, testing is still needed to fix any problems with the interface. These findings give a good foundation for designing an app for UNIBEN, but they also show that we need to adapt these ideas to fit our unique local context.

Table 2.1: Comparative Analysis of Empirical Studies on Recycling Applications

Study (Author, Year)	**Location (Country)**	**Methodology**	**Key UI/UX Features**	**Evaluation Metric(s)**	**Key Outcomes/Findings**
Bonino et al. (2016)	Turin, Italy	Co-design, Think-aloud Protocol	Barcode scanning, Waste sorting guide, Bin location maps	Task Success Rate	Mixed success rates (62.5%–87.5%); identified UI challenges in bin location tasks.

Purbo et al. (2024)	Kesugihan, Indonesia	Design Thinking	Pickup requests, Balance withdrawals for recyclables, Waste bank info	System Usability Scale (SUS)	"Good" SUS score of 71; economic incentives boosted engagement.
Soleh & Maukar (2024)	Jakarta, Indonesia	Design Thinking	Pickup scheduling, Points-based rewards, Trash reporting feature	System Usability Scale (SUS), Task Success Rate	"Good" SUS score of 80.29; very high success rates (92%–100%) for core tasks.

2.5 The Nigerian Context

While we can learn from international examples, we cannot simply copy them for Nigeria. A successful recycling app at the University of Benin must be designed for Nigeria's unique challenges and the specific environment of the campus.

Nigeria has a serious waste management problem. The country produces millions of tons of solid waste every year, but only a small fraction (20-30%) is collected and managed properly, as reported by sources like Punch Nigeria. This leads to environmental damage and health risks (Ojewale & Owojori, 2020). The national recycling rate is very low, especially for plastics, with some estimates putting it below 15%. At the same time, Nigeria has a digital divide. While there are many internet users, more than half of the population is still offline, according to 2024 data from DataReportal. For those online, issues like poor network connectivity and the high cost of data are major problems. This means a mobile app for this

environment must be simple, work well on slow connections, and be easy for people with limited digital skills to use.

Despite these national challenges, the University of Benin is a good place for a focused recycling project. The campus is a contained area with a large and steady amount of daily waste—over 25,000 kg (Uwadiae et al., 2017). This makes collection and monitoring easier than in a large city. A study of the waste on campus found that a large portion is made of recyclable materials like plastics/rubber (26.67%) and paper (18.65%) (Uwadiae et al., 2017). Furthermore, university students have been shown to be open to environmental education and positive changes in their attitudes towards waste segregation (Ogunyemi et al., 2023). There is also strong support from the university administration, which recently won a European Union grant for a project on Sustainable Plastic Waste and Recycling Management (SWARM), as reported by UNIBEN News. These factors—a concentrated problem, a receptive audience, and institutional support—make UNIBEN an ideal place to pilot a recycling app that could later be used in other Nigerian universities.

2.6 Synthesis and Identification of the Research Gap

The literature shows that mobile apps have the potential to encourage recycling. Theories like the Theory of Planned Behavior explain how UI/UX features can influence people's attitudes and behaviors. Studies from Italy and Indonesia also show that user-centered design and features like rewards can be very effective. However, when we look at this research from a Nigerian perspective, we see several important gaps that this study will address.

First, there is a **Contextual Gap**. The main studies reviewed were done in Italy and Indonesia, countries with better recycling infrastructure and higher digital literacy than Nigeria. For example, Italy's recycling rate is much higher than Nigeria's, and even in the U.S., which has a 32% recycling rate, contamination remains a major issue. Simply copying app designs from these places is unlikely to work in Nigeria without major changes.

Second, there is a **Demographic Gap**. The existing studies focused on the general public in cities, not on university students. Students have unique lifestyles, live in different arrangements like hostels, and are heavily influenced by their peers. An app for UNIBEN students needs to be designed for their specific campus life.

Third, the literature mostly ignores the **Logistical Gap**. The apps in the reviewed studies assume that there is a reliable waste collection service. This is not always the case in Nigeria, where collection can be irregular. An app that doesn't account for this unpredictability will fail because it will lose the trust of its users.

Finally, there is a **Socio-Technical Gap**. No research has properly looked at how to design a UI/UX for a place with both low digital literacy and low trust in systems. This requires a design that is extremely simple for new users and also very transparent and reliable to build confidence.

This study is needed to fill these gaps. By designing, developing, and testing a mobile recycling app specifically for the University of Benin, this research will provide a new and important case study on digital environmental projects in a sub-Saharan African context. It will offer valuable lessons on how UI/UX design can be adapted to promote sustainable habits in communities with similar challenges.

CHAPTER 3

METHODOLOGY

This chapter details the methodology used to design and prototype the "UNICYCLE" mobile application prototype. It covers the analysis of the existing problems at the University of Benin, the design of the proposed system, and the User-Centered Design (UCD) process that guided the project from conception to the final, refined prototype.

3.1 Research Methodology

This project employed a **User-Centered Design (UCD)** methodology, which places the needs, behaviors, and limitations of the end-user at the center of every stage of the design and development process. Specifically, the project was structured around the five phases of the **Design Thinking** framework: **Empathize, Define, Ideate, Prototype, and Test**.

This iterative approach was chosen because it is highly effective for solving complex, human-centered problems. It ensures that the final solution is not just technically functional but also usable, desirable, and genuinely effective for its target audience.

3.1.1 Application of the Design Thinking Model

- **1. Empathize:** The project began with user research to gain a deep, empathetic understanding of the recycling problem on the UNIBEN campus. This was achieved through questionnaires and interviews (detailed in Section 3.4).
- **2. Define:** The qualitative and quantitative data from the "Empathize" phase was analyzed to define the core problem. The findings (detailed in Section 3.3) showed the problem was a combination of a knowledge gap, a dysfunctional physical infrastructure, and a lack of motivation.
- **3. Ideate:** With a clear problem statement, this phase involved brainstorming features to address the defined needs. This led to the concepts for the educational guides, gamification, and the real-time bin locator.
- **4. Prototype:** The ideas were translated into a tangible, high-fidelity prototype (Iteration 1.0, shown in Chapter 4). This interactive model was built to be tested with real users.

- **5. Test:** The first prototype was evaluated by representative users. Feedback from this phase (e.g., "move the 'Next' button to the bottom," "add a logout confirmation") directly informed the "Second Iteration" (Iteration 2.0, also in Chapter 4), demonstrating the iterative and responsive nature of the UCD process.

3.2 Analysis of Existing Systems

An analysis of existing systems was conducted to identify gaps and justify the need for a new, tailored solution. This analysis covered both digital competitors and the existing physical system.

3.2.1 Digital Recycling Applications

As identified in the literature review, applications like "WasteApp" (Bonino et al., 2016) and "SISAKU" (Soleh & Maukar, 2024) demonstrate the effectiveness of user-centered design, gamification, and utility features like barcode scanners. However, these systems have a critical weakness: they are designed for different socio-economic contexts (e.g., Italy, Indonesia) and assume a reliable municipal waste collection infrastructure.

3.2.2 Existing Physical System (University of Benin)

The "Empathize" phase of this research included an investigation into the current, non-digital recycling "system" at the University of Benin.

- **User Perspective:** Questionnaire data revealed that the vast majority of the campus community is unaware that any dedicated recycling bins exist.
- **Administrative Perspective:** An interview with personnel involved in campus waste management confirmed the users' perception. The existing infrastructure is minimal, mostly dysfunctional, and lacks a communication system to inform the community of its status.

This analysis confirmed that a successful digital solution could not simply mimic international apps. It must be designed to solve the core local problem: the disconnect between users and a dysfunctional physical infrastructure.

3.3 Problem Definition (Findings from the "Empathize" Phase)

The "Empathize" phase (consisting of questionnaires and interviews) defined the specific problems the "UNICYCLE" app must solve. The key findings were:

1. **Lack of Waste Segregation:** Waste is hardly ever separated by the campus community before disposal.
2. **Significant Knowledge Gaps:** A large portion of respondents did not know what materials could be recycled.
3. **Low Awareness of Infrastructure:** Users were unaware of the few dedicated bins on campus, which were confirmed to be in a dysfunctional state.
4. **High Willingness and Motivation:** A majority of respondents agreed their personal efforts could make an impact and stated they would be more likely to recycle if incentives were provided.
5. **Demand for a Digital Tool:** The community was very interested in a mobile app to aid this activity. The most requested feature was a "guide on sorting recyclable waste."
6. **Critical Need for Simplicity:** Respondents strongly emphasized that the application must be "simple and easy to navigate."

3.4 Overview of the Proposed System ("UNICYCLE")

The proposed system, "UNICYCLE," is a high-fidelity mobile application prototype designed as a socio-technical solution to the problems identified in Section 3.3. It addresses the user needs by combining education, motivation, and real-world utility.

The core functions of the proposed system (detailed in Chapter 4, Iteration 2.0) are:

- **Education:** "Information on Recycling," "How to Recycle," and "Benefits of Recycling" modules to address the knowledge gap.
- **Interactive Sorting:** A **Bar Code Scanner** that allows users to scan a product's barcode to learn its recycling status, directly fulfilling the top user request for a "sorting guide."
- **Motivation (Gamification):** A **Quiz** module and a **Profile** screen that tracks user statistics ("Items Recycled," "CO2 Saved") and provides a "Member Status" to deliver the incentives users requested.

- **Utility (Bridging the Physical Gap):**
    1. A user-facing **"Location"** feature that shows a map of campus bins with their real-time status ("Not Full" or "Full").
    2. A corresponding **"Admin Panel"** for waste management personnel to log in and update the bin statuses, making the physical system visible and reliable for the first time.

3.5 Application Flow Diagram

The structure of the mobile application is designed to provide a simple and intuitive user journey. The flow diagram in Figure 3.1 illustrates the primary navigation paths a user will take when interacting with the application, from initial entry to accessing the core features.

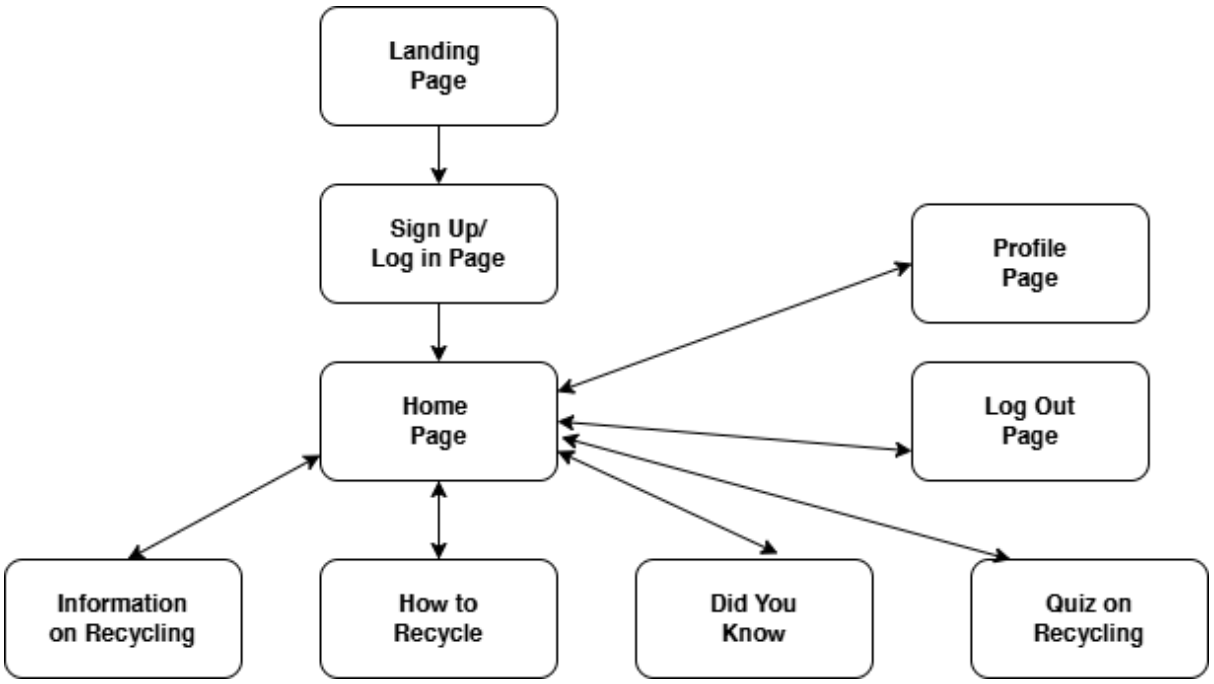


Figure 3.1: Application Interaction Flow

Explanation of the Flow:

1. **Entry and Authentication:** The user's journey begins at the **Landing Page**, which serves as the initial entry point. From here, the user proceeds to the **Sign Up/Log in Page** to either create a new account or authenticate their existing credentials.
2. **Homepage as Central Hub:** Upon successful login, the user is directed to the **Home Page**. This screen acts as the central hub of the application, providing access to all primary features and user management options.
3. **Core Features:** The Home Page provides direct navigation to the four main educational and engagement modules:
    - **Information on Recycling:** Provides general knowledge about recycling.
    - **How to Recycle:** Offers specific guides and instructions.
    - **Did You Know:** Presents interesting facts to keep users engaged.
    - **Quiz on Recycling:** A gamified feature to test user knowledge.
4. **User and Session Management:** From the Home Page, the user can also navigate to their **Profile Page** to manage their account details or directly to the **Log Out Page** to end their session.

This flow is designed to be straightforward, ensuring that users can easily access the key functionalities of the application from a central point, which is a core principle of good user experience design.

3.6 Data Collection and Evaluation Methods

This study used a mixed-methods approach to data collection, occurring at two distinct stages:

1. **"Empathize" Phase (Requirements Gathering):**
    - **Questionnaire:** A structured questionnaire (based on the template in) was distributed to the campus community to gather quantitative and qualitative data on current habits, knowledge gaps, and desired features.
    - **Semi-Structured Interviews:** A key-informant interview was conducted with waste management personnel to understand the systemic and infrastructural challenges.
2. **"Test" Phase (Prototype Evaluation):**
    - **Usability Testing:** The first prototype (Iteration 1.0) was tested by a sample of representative users.

- **Think-Aloud Protocol:** During testing, users were encouraged to verbalize their thoughts, allowing for the identification of specific usability issues (e.g., the poorly placed "Next" button).
- **System Usability Scale (SUS):** Following the test, each participant completed the 10-item SUS questionnaire. This industry-standard tool was used to generate a quantitative score, providing an objective measure of the prototype's perceived usability.

3.7 Ethical Considerations

To ensure the research is conducted ethically, the following measures will be taken:

- **Informed Consent:** All participants will be fully informed about the purpose of the study and what their participation will involve. Written consent will be obtained before they take part in any interview or testing session.
- **Confidentiality:** The identity and personal information of all participants will be kept confidential. Any data collected will be anonymized to protect their privacy.
- **Voluntary Participation:** Participants will be informed that their involvement is completely voluntary and that they have the right to withdraw from the study at any point without any negative consequences.

CHAPTER 4

IMPLEMENTATION

4.1 Introduction

This chapter presents the implementation of the high-fidelity prototype for the mobile recycling application, named "UNICYCLE." This prototype is the direct outcome of the initial phases of the Design Thinking methodology outlined in Chapter 3, translating the insights from the Empathize, Define, and Ideate stages into a tangible, interactive design.

The screens presented in this chapter represent the first design iteration of the application. This version was developed based on initial user requirements, the findings from the literature review, and established design principles from the field of Human-Computer Interaction (HCI). This prototype serves as the primary instrument for the "Test" phase of the research, allowing for the collection of qualitative and quantitative data from the target users—the students of the University of Benin.

4.2 Tools and Technologies

The high-fidelity prototype was created using modern digital design and prototyping tools. A vector graphics editor, Figma, was used to design the individual screens, create the visual assets, and establish a consistent design language. This tool is widely used in UI/UX design for its ability to create realistic simulations of user interactions and interactive button states

(Saptaputra et al., 2023). The interactive elements, such as button clicks and screen transitions, were then linked within the tool to simulate the user flow and create a realistic, clickable prototype that mimics the behavior of a semi developed application.

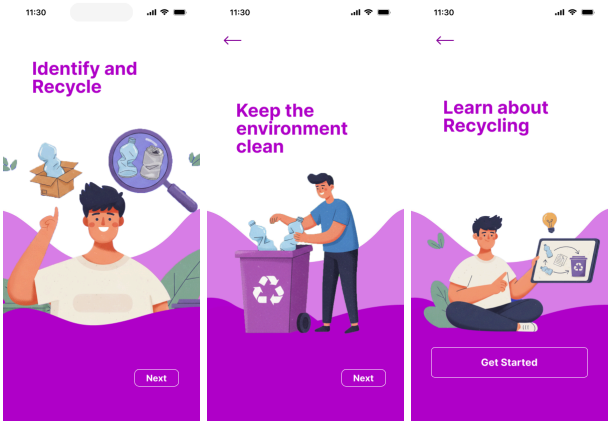
4.3 The "UNICYCLE" High-Fidelity Prototype (First Iteration)

The following sections present the key screens and user flows of the UNICYCLE prototype. Each section describes a specific part of the user journey, explaining the design choices and how they are grounded in the project's objectives to educate, motivate, and facilitate recycling.

4.3.1 Onboarding and User Authentication

The initial interaction a user has with the application is designed to be welcoming, informative, and seamless. The flow guides the user from understanding the app's value to creating an account.

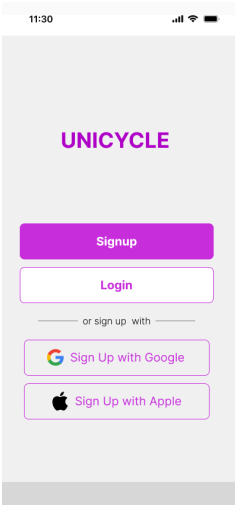
Onboarding Screens: Before signing up, new users are greeted with a brief, three-step onboarding sequence (Figure 4.3). These screens use friendly illustrations and concise text to quickly communicate the app's core purpose: to help users identify recyclables, keep the environment clean, and learn about recycling. This sequence concludes with a clear call-to-action, "Get Started."



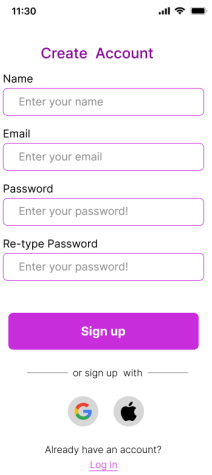
(a) (b) (c)

Figure 4.3 Onboarding Page

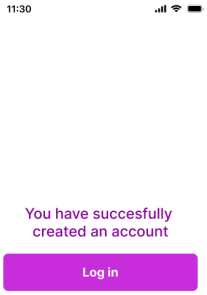
Authentication Flow: The authentication process provides multiple, convenient options for users. The main landing page (Figure 4.31) offers standard **Signup** and **Login** buttons, alongside social sign-up options with **Google** and **Apple** to reduce friction. The account creation screen is a standard form. Upon successful registration, the user receives a clear confirmation message, an important feedback mechanism that adheres to the heuristic principle of "visibility of system status." The login and password recovery flows are designed to be straightforward and ensure users can easily access or recover their accounts.



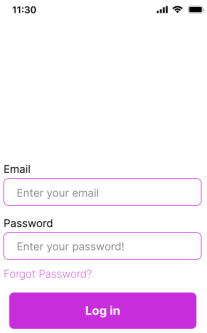
(a)



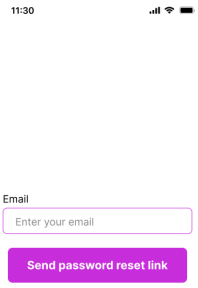
(b)



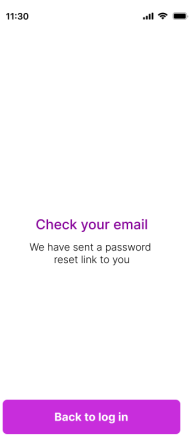
(c)



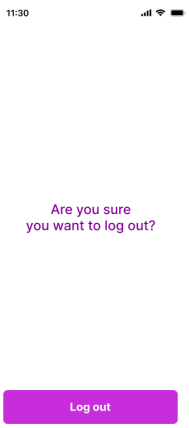
(d)



(e)



(f)



(e)

Figure 4.31 Authentication Flow

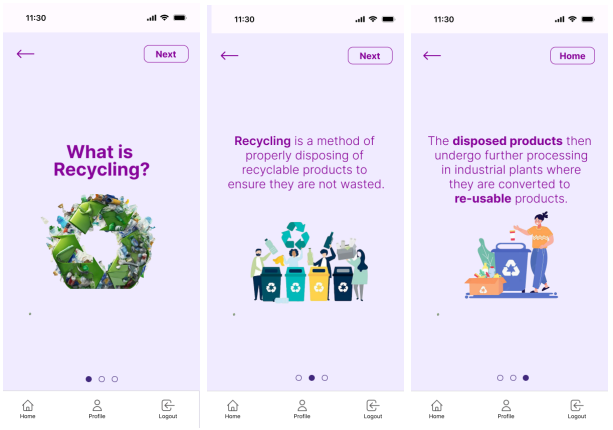
4.3.2 The Homepage: The Central Hub

The Homepage is the main dashboard of the application. It is designed to be a personalized and action-oriented hub. A welcoming message ("Welcome Richard") adds a touch of personalization. The core features are presented as large, colorful buttons with clear labels and icons, allowing for easy navigation. A persistent bottom navigation bar provides constant access to **Home**, **Profile**, and **Logout** functions, ensuring a consistent and predictable user experience.

4.3.3 Core Educational Modules

A primary objective of the app is to address the documented knowledge gap in recycling, which is a significant barrier to participation. Research conducted specifically at the University of Benin confirmed a "significant disparity in both knowledge and attitudes toward waste segregation" between students who had received environmental education and those who had not (Erhabor, 2024). The following modules directly target this gap.

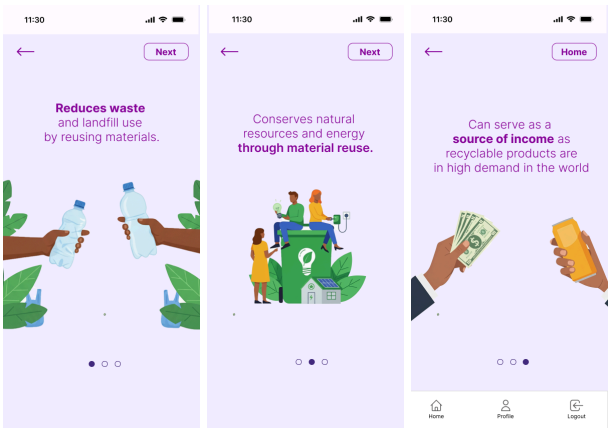
- **Information on Recycling:** This module explains the fundamental concept of recycling, from its definition to the industrial process, using simple text and supportive illustrations.



(a) (b) (c)

Figure 4.32 Information on Recycling

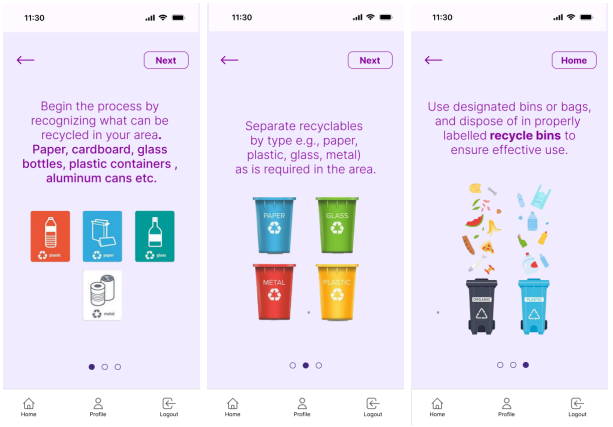
- **Benefits of Recycling:** This section highlights the positive impacts of recycling, focusing on waste reduction, resource conservation, and potential economic benefits. This aims to improve a user's "Personal Attitude" toward the behavior, a key component of the Theory of Planned Behavior (Ajzen, 1991).



(a) **(b)** **(c)**

Figure 4.33 Benefits of Recycling

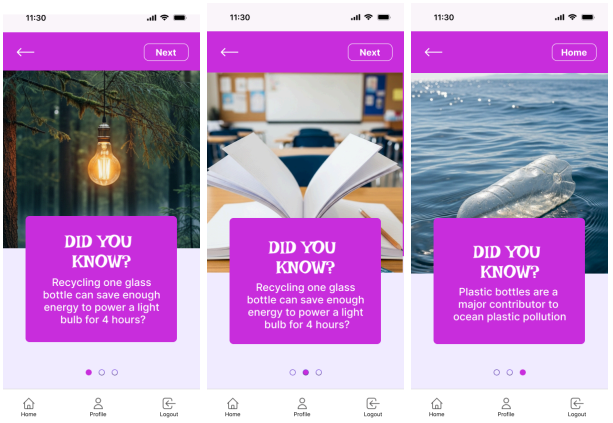
- **How to Recycle:** This practical guide (Figures 4.35) provides actionable steps for users, teaching them how to recognize recyclable materials, separate them by type, and use designated bins. By simplifying the task, this feature directly enhances "Perceived Behavioral Control" (Ajzen, 1991), a key factor in influencing recycling intentions.



(a) (b) (c)

Figure 4.34 How to Recycle

- **Did You Know?:** This feature is designed for sustained engagement, presenting interesting, bite-sized facts about recycling and environmental impact in a visually appealing card format.

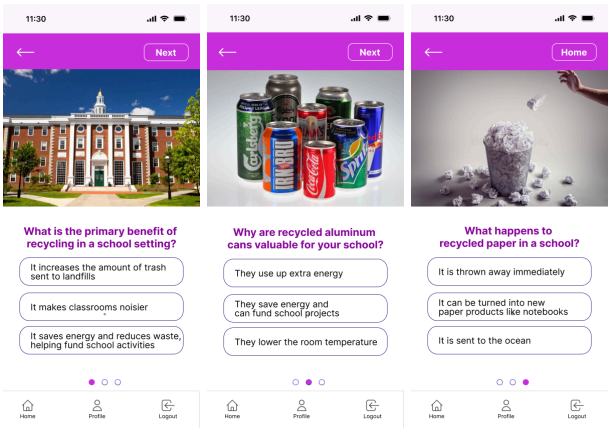


(a) (b) (c)

Figure 4.35 Did you know?

4.3.4 Gamification and Engagement

To motivate users and reinforce learning, the app incorporates a quiz module. Gamification is recognized as a "promising strategy" for stimulating motivation, especially for activities that may be perceived as tedious or unrewarding, such as recycling (Aguiar-Castillo et al., 2018). This feature (Figures 4.37) tests users' knowledge in an interactive, multiple-choice format, making the educational experience more engaging.



(a) (b) (c)

Figure 4.36 Quiz Section

4.3.5 Utility and Campus Integration

The "Bin Status" feature (Figure 4.38) is a key utility that connects the digital app to the physical campus environment. It displays images of actual recycling bins at various locations (e.g., Hall 3, Basement) and provides their real-time status: **"Not Full - Available"** or **"Full - Not Available."** This feature directly addresses a major user pain point. Research by Bonino et al. (2016) noted that the absence of real-time data, such as the "current fill-level of collection bins," was a relevant factor for users that was not addressed by most municipal apps.[1] This feature is designed to fill that gap.

Figure 4.37 Location

4.3.6 Session Management

Finally, the prototype includes a clear logout process. To prevent accidental logouts, a confirmation screen (Figure 4.39) is presented to the user, a standard usability practice that gives the user final control over their session.

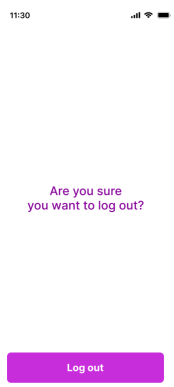


Figure 4.38 Log Out screen

4.4 Design Rationale and UI/UX Principles in Practice

The visual and interactive design of the UNICYCLE prototype was guided by specific UI/UX principles intended to create an effective and user-friendly experience tailored to the UNIBEN context.

4.4.1 Color Palette and Branding

The choice of a vibrant purple as the primary color was a deliberate branding decision. This color was selected to align with the visual identity of the University of Benin, creating an immediate sense of familiarity and belonging for the student users. Color is a "powerful communication mechanism" that can enhance brand recognition. Furthermore, in user interface design, the specific "white-on-purple" combination has been shown to perform well and is recommended for low-to-medium cognitive load environments, making it a suitable choice for this application's educational and task-oriented sections (He et al., 2024).

4.4.2 Interactive Feedback and System Visibility

A core principle of interaction design is **feedback**, which is defined as sending back information about what action has been done and what has been accomplished. In the UNICYCLE prototype, this is implemented through button states. When a user hovers over or taps a button, its color is designed to darken slightly. This "active" state is a

microinteraction that provides instant visual feedback, acknowledging the user's input. This makes the application feel more responsive and intuitive, which in turn enhances user satisfaction and their intention to continue using the application.

4.4.3 Leveraging User Familiarity for Feedback

The design of the quiz module leverages deeply ingrained user psychology regarding color associations. For feedback on answers, the prototype is designed to use:

- **Green** to indicate a correct answer.
- **Red** to indicate an incorrect answer.

This choice is intentional, as these colors have strong, established symbolic associations. Research confirms that green is strongly associated with "approach motivation" (Poirel et al., 2022). This aligns with established conventions of using green for "yes" or "go" and red for "warn or stop" (Bao & Liu, 2018). By using this familiar "color scheme" and "information presentation style," the application reduces cognitive load, allowing the user to focus on learning the material rather than trying to interpret the interface.

4.5 Second Iteration: Design Refinement Based on User Feedback

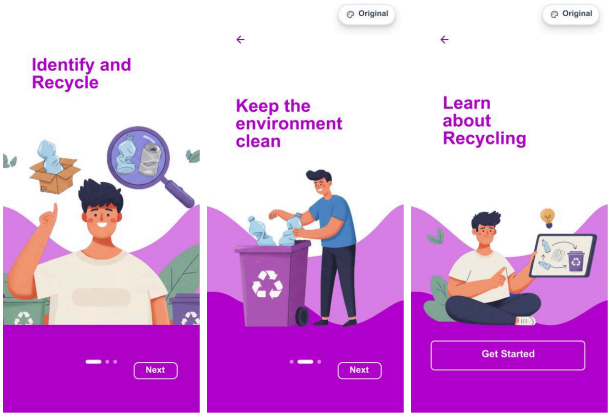
Following the "Test" phase of the Design Thinking methodology, the first prototype (Iteration 1.0) was evaluated by a sample of target users. This usability testing revealed several key areas for improvement. The feedback was synthesized and directly implemented to create a second, more refined high-fidelity prototype (Iteration 2.0).

This section details the significant changes made between the first and second iterations, demonstrating the tangible results of the User-Centered Design (UCD) process.

4.5.1 Enhanced Onboarding and Authentication

A key issue noticed from user feedback indicated that the initial login and registration process, while functional, felt generic. The new iteration focuses on building a stronger brand identity and providing a friendlier, more guided user experience.

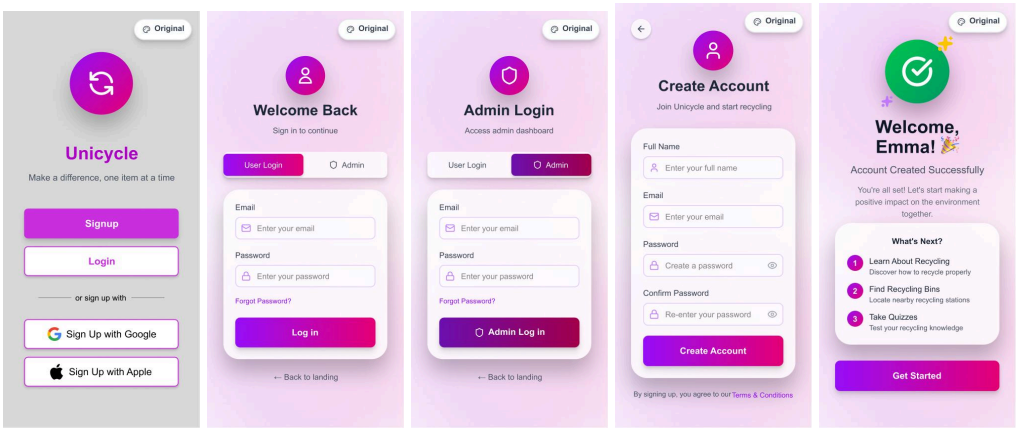
- **Refined Onboarding and Landing:** More animation was added to the onboarding page, giving it a better aesthetic and grabbing more of the user's attention. A user pointed out how the animation added gave the app a better experience.



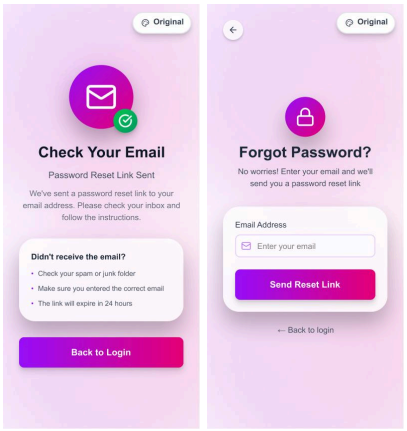
(a) (b) (c)

Figure 4.5 Revised Onboarding

- **Improved Forms:** The login and sign-up screens were redesigned using a modern card-based layout. Key improvements include the addition of icons within text fields for better visual guidance, a password visibility toggle (the "eye" icon) to reduce user error, and a clear link to "Terms & Conditions," a best practice for building user trust.



(a) (b) (c) (d) (e)



(f) (g)

Figure 4.51 Revised Authentication flow

- **Welcoming and Guidance:** A significant addition is the new "Welcome, Emma!" screen. Instead of simply confirming account creation, this screen celebrates the user's success and provides a "What's Next?" section, which actively guides the new user toward the app's core features ("Learn About Recycling," "Find Recycling Bins," "Take Quizzes"). This immediately orients the user and improves the onboarding experience.

4.5.2 Improved Information Architecture and Navigation

Users found the original homepage's full-width buttons to be overwhelming. The navigation was also revised to elevate the importance of a key feature.

- **New Homepage:** The homepage was completely redesigned into a clean, scannable, card-based layout. Each feature is now presented as a distinct card with an icon, title, and descriptive subtitle. This layout is more modern, less cluttered, and allows users to find information more quickly.

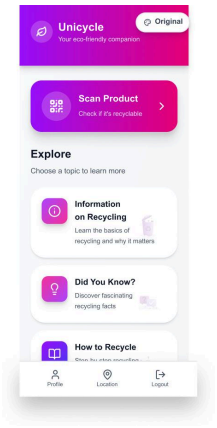


Figure 4.52 Homepage

- **Revised Bottom Navigation:** The bottom navigation bar was updated from "Home, Profile, Logout" to "Home, Profile, **Location**, Logout." This critical change makes the "Bin Status Locator" (now "Location") a primary, top-level feature, accessible from anywhere in the app. This decision was based on user feedback that finding bin locations was one of their most desired functions.
- **Improved Logout:** A common piece of user feedback on the first prototype was the abruptness of the logout process. Users expressed the need for **"a log out pop up"** to show before being logged out, preventing accidental clicks. This feedback was addressed by replacing the full-screen logout page (Figure 4.39) with a modern, non-intrusive modal overlay. This modal (Figure 4.53) not only confirms the user's intent but also provides clearer context about the consequence of their action ("You'll need to log in again..."), which is a significant usability improvement.

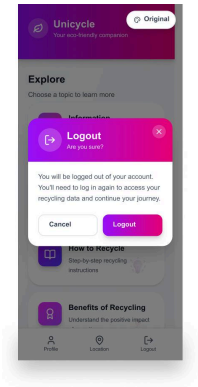


Figure 4.53 Revised Log Out Confirmation

4.5.3 Enhanced Educational and Gamification Modules

Feedback on the first iteration showed that while users appreciated the educational content, the quiz felt incomplete and unmotivating. A key usability finding was that users found the "Next" button at the top of the sectional pages (see Figure 4.35) were difficult to reach. As one user noted, the button **"would be better below and not above, for ease of navigation."** In response, the "Next" button in the second iteration (Figures 4.5 and 4.55) was moved to the bottom of the screen in some sections like the Quiz section, while a scrolling feature was added in all pages, reducing the need to switch across multiple pages, easing the burden on users, and making navigation easier overall.

Redesigned Educational Content (Figures 4.54): The full-screen carousel slides were replaced with scrollable, card-based article pages. The "How to Recycle" module was changed to a checklist format, which is far more practical and actionable for a user trying to learn a process.

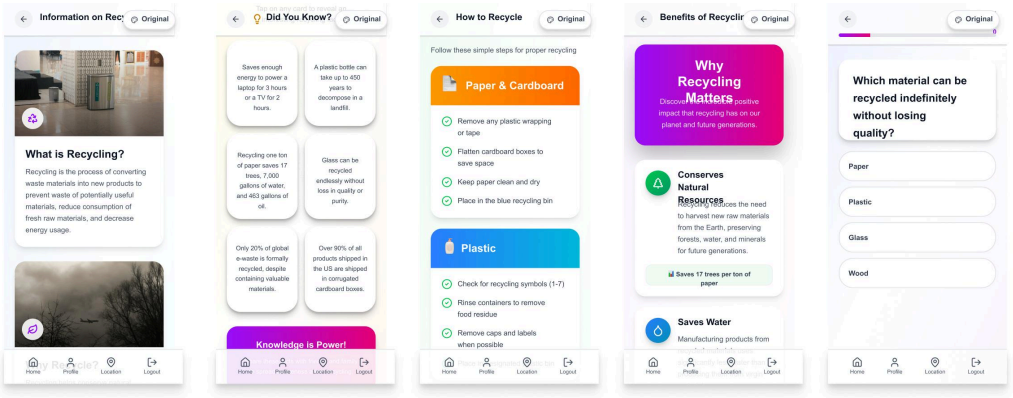


Figure 4.54 Revised Information on Recycling

Interactive Quiz Feedback (Figures 4.55): The quiz was significantly enhanced. It now features a progress bar and provides immediate, color-coded feedback. It shows how an incorrect answer ("Paper") is marked in **red**, while the correct answer ("Glass") is marked in **green**. An explanation is also provided, which "closes the loop" and ensures the quiz is an effective learning tool, not just a test.

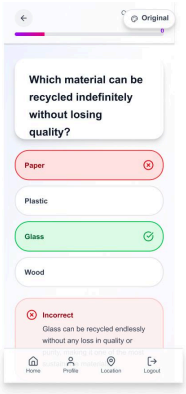


Figure 4.55 Interactive Feedback

Gamification Loop (Figures 4.56): To provide motivation, two key screens were added. A "Quiz Completed!" screen provides a score and a sense of accomplishment. More importantly, a "Profile" screen was introduced. This screen gamifies the entire experience by showing users tangible metrics of their progress ("Items Recycled," "Quizzes Completed") and a "Member Status" (e.g., "Gold"), directly tying their actions to rewards and status.

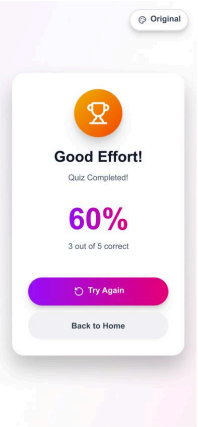


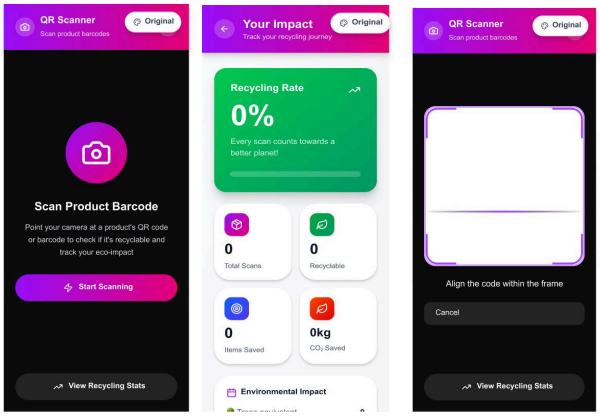
Figure 4.56 Gamification Loop

4.5.4 Introduction of Interactive Sorting and Impact Tracking

A significant finding from the "Empathize" phase was that users felt overwhelmed by the lack of knowledge and desired a simple, direct "guide on sorting" as the top feature. The static guides in Iteration 1.0 were a first step, but feedback indicated a need for a more immediate and interactive solution.

To address this, a "Bar Code Scannner" feature was introduced in Iteration 2.0. This feature allows a user to scan a product's barcode to instantly check if it is recyclable and, more importantly, "track your eco-impact." This design choice is supported by literature, such as the WasteApp study by Bonino et al. (2016), which included a barcode scanner to "ease the waste recognition process," as well as other modern applications that use scanning to help users identify and sort waste.

This feature is directly integrated into the gamification loop. As shown in Figure 4.48, scanning an item allows the user to "View Recycling Stats," which leads to an "Your Impact" dashboard. This dashboard provides users with real-time, personal metrics on their "Recycling Rate," "Total Scans," "Items Saved". This data directly populates the main Profile, connecting the user's physical action of recycling to a tangible digital reward and reinforcing the motivational framework.



(a) **(b)** **(c)**

Figure 4.57 Bar Code Scanner

4.5.5 Admin and System Functionality

A critical piece of feedback was user skepticism about the accuracy of the "Bin Status" feature. To solve this, an administrative backend was designed.

- **Admin User Role (Figures 4.57):** The login screen now features a toggle for "User Login" and "Admin," establishing a separate user role.

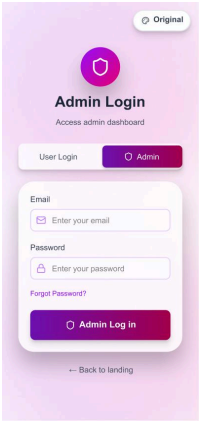


Figure 4.58 Admin Authentication

- **Bin Management System (Figure 4.58):** The "Admin Login" leads to a "Bin Management" dashboard. This screen allows an administrator to see a summary of all bins ("Total Bins," "Full Bins," "Available") and, most importantly, manually toggle

the status of each bin on campus (e.g., from "Free" to "Full"). This backend system ensures that the data shown to students on the "Location" screen is accurate and reliable, which is essential for building long-term user trust.

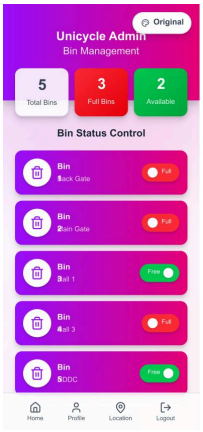


Figure 4.59 Bin Management

4.6 The System Usability Scale (SUS) as an Evaluation Tool

The System Usability Scale (SUS) is a widely recognized and trusted tool in the field of User-Centered Design. Its essence lies in its combination of simplicity and reliability. It consists of a 10-item questionnaire where users rate statements on a Likert scale (from "Strongly Disagree" to "Strongly Agree").

The primary usefulness of the SUS is its ability to distill complex, subjective user feedback into a single, global score, typically ranging from 0 to 100. This score is not a percentage but a comparative metric. Its true value comes from being highly benchmarkable; based on extensive industry research, the average SUS score across thousands of different products and systems is 68. This allows a researcher to objectively grade a prototype's usability (e.g., "Poor," "Good," "Excellent"). As seen in the literature review, it is a standard tool used in similar app development projects to measure user satisfaction and ease of use (Purbo et al., 2024; Soleh & Maukar, 2024). In the context of this project, using the SUS provides a credible, quantitative validation of the design iterations and confirms whether the objective of creating a simple, easy-to-navigate application was met.

4.6.1 SUS Test Results and Data

Ten (10) participants, representing the target user demographic of the University of Benin community, were asked to perform a series of tasks using the "UNICYCLE" prototype (Iteration 2.0). These tasks included creating an account, finding the "How to Recycle" guide, answering the Quiz, and locating a nearby recycling bin.

After the session, each participant completed the 10-item SUS questionnaire.

The questionnaire consists of the following 10 statements, originally developed by Brooke (1986). Participants were asked to rate each statement on a 5-point Likert scale, ranging from "Strongly Disagree" (1) to "Strongly Agree" (5):

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

The individual scores, which are calculated to fall on a scale of 0 to 100, are presented in Table 4.1.

Table 4.1: System Usability Scale (SUS) Scores

Participant	SUS Score (0-100)
User 1	97.5
User 2	97.5
User 3	62.5
User 4	87.5
User 5	90.0
User 6	87.5
User 7	85.0

User 8	92.5
User 9	100.0
User 10	80.0

4.6 Calculation and Analysis of Final Score

To determine the final usability score for the "UNICYCLE" prototype, the scores from all 10 participants were averaged.

- Calculation:
  (97.5 + 97.5 + 62.5 + 87.5 + 90.0 + 87.5 + 85.0 + 92.5 + 100.0 + 80.0) / 10
  = 870 / 10
  = 87.0

The final average System Usability Scale (SUS) score for the "UNICYCLE" prototype is 87.0.

An 87.0 is considered an "Excellent" result. This score places the "UNICYCLE" prototype well above the industry average of 68 and in the top 10-15% of all products tested. This score is significantly higher than the "Good" scores of 71 and 80.29 reported in the literature review for similar applications (Purbo et al., 2024; Soleh & Maukar, 2024).

This high score provides strong quantitative validation that the User-Centered Design (UCD) process was successful. The "Empathize" phase (Chapter 3) identified a critical user requirement: the application must be "simple and easy to navigate." The usability testing of Iteration 1.0 revealed flaws that were directly addressed in Iteration 2.0. This final score of 87.0 demonstrates that the design changes—such as the improved navigation bar, the

card-based homepage, and the relocated buttons—were highly effective and resulted in a prototype that users find exceptionally usable, intuitive, and easy to use.

CHAPTER 5

SUMMARY

5.1 Summary of the Study

This project was undertaken to address the significant and persistent challenge of waste management at the University of Benin. The "Empathize" phase of the research confirmed that the campus community, while willing to participate in pro-environmental activities, is hindered by three primary barriers: a critical lack of knowledge on what materials are recyclable, a lack of awareness of the (mostly dysfunctional) bin infrastructure, and a lack of incentives to motivate consistent recycling behavior.

The primary aim of this study was to design and develop a high-fidelity mobile application prototype, "UNICYCLE," using a User-Centered Design (UCD) approach to directly address these barriers. The project was structured around the five-phase Design Thinking model.

The "Define" phase, informed by questionnaire and interview data, established the core user requirements: a simple, easy-to-navigate application with a primary feature for guiding users on how to sort waste. The "Ideate" phase translated these requirements into a set of features, which were then built in the "Prototype" phase as a first iteration (Iteration 1.0), as detailed in Chapter 4. This initial prototype included educational modules, a quiz, and a basic bin locator.

This first iteration was then subjected to the "Test" phase, where usability testing with target users revealed specific, actionable flaws. Key feedback included that the "Next" button was awkwardly placed at the top of the screen, and the logout function was abrupt and lacked a necessary confirmation dialog.

This feedback directly informed a second design cycle, resulting in the final, refined prototype (Iteration 2.0). This iteration implemented significant improvements, such as repositioning navigation buttons to the bottom of the screen for better ergonomics, adding a confirmation modal for the logout action, redesigning the homepage into a cleaner card-based layout, and enhancing the gamification and educational modules to be more interactive and rewarding.

5.2 Recommendations for Future Work

Based on the success of this design project and its limitations, the following steps are recommended for future work:

1. **Full-Scale Development:** The immediate next step is to transition from design to development. This would involve a software development team building a functional front-end and a robust back-end for the application based on the Iteration 2.0 prototype.
2. **Collaboration with UNIBEN Administration:** To ensure the "Location" feature is viable, a formal partnership with the university's waste management authorities is essential. This would involve integrating the "Admin Panel" (Figure 4.41) with their operational workflow, allowing designated staff to update bin statuses in real-time.
3. **Expansion of Gamification:** The user research indicated a strong desire for incentives. Future development should fully build out the "Profile" and "Member Status" features (Figure 4.46) to connect with tangible, real-world rewards, such as mobile data, cafeteria discounts, or faculty-wide competitions.
4. **Longitudinal Pilot Study:** Once the app is built, a pilot study should be conducted with a cohort of UNIBEN community members over a full academic semester. This would allow for the collection of quantitative data on its real-world effectiveness, measuring its impact on user knowledge, attitudes, and, most importantly, actual recycling behavior on campus.

5.3 Conclusion

This research project successfully achieved all its stated objectives. The primary aim of the study—to design and develop a user-centered mobile application prototype that applies UI/UX principles to facilitate recycling—was met and validated.

The final prototype, "UNICYCLE" Iteration 2.0, stands as a comprehensive and highly usable solution. The "Excellent" SUS score of 87.0 provides strong quantitative evidence that the UCD methodology was effective in creating a system that users find simple, intuitive, and easy to navigate, which was the top requirement gathered during the "Empathize" phase.

The prototype directly solves the specific problems identified at the University of Benin:

1. It addresses the **knowledge gap** through its educational guides and the interactive QR scanner.
2. It addresses the **motivation gap** through a gamified profile that tracks a user's personal impact and provides status-based rewards.
3. Most critically, it solves the **local infrastructural gap** by proposing a socio-technical system where the Admin Panel and the user-facing "Location" feature connect the dysfunctional physical bins to a reliable digital information network.

This project demonstrates that by applying a rigorous iterative design process, it is possible to create a digital tool that is not only highly usable but also specifically tailored to solve the unique socio-technical challenges of the UNIBEN campus community.

REFERENCES

Adewoyin, O., Akindusoye, T., Ayogu, B., & Daramola, C. Y. (2025). Medstracker: a design science approach to medication management in Nigeria. *AI & Society*.

admin. (2025, February 19). *UNIBEN wins European Union grant for sustainable plastic waste and recycling management project*. UniBEN NEWS. https://news.uniben.edu/uniben-wins-european-union-grant-for-sustainable-plastic-waste-and-recycling-management-project/

Agbebaku, H. U. (2021). Perception of residents on the menace of solid waste on environmental quality in Benin City, Edo State, Nigeria. *Nigerian Journal of Environmental Sciences and Technology, 5*(2), 290–306. https://doi.org/10.36263/nijest.2021.02.0233

Aguiar-Castillo, L., Clavijo-Rodriguez, A., De Saa-Perez, P., & Perez-Jimenez, R. (2019). Gamification as an approach to promote tourist recycling behavior. *Sustainability, 11*(8), 2201. https://doi.org/10.3390/su11082201

Aguiar-Castillo, L., Rufo-Torres, J., De Saa-Pérez, P., & Perez-Jimenez, R. (2018). How to Encourage Recycling Behaviour? The Case of WasteApp: A Gamified Mobile Application. *Sustainability, 10*(5), 1544. https://doi.org/10.3390/su10051544

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211.(https://doi.org/10.1016/0749-5978(91)90020-T)

Ali, M., & Yusuf, T. L. (2023). Solid Waste Generation and Management in Nigeria's 36 States: An In-Depth Analysis. *Delta State University Journal of Pure and Applied Sciences, 3*(1), 1-13.

Ambrosio-Santiago, B., Paico-Campos, J., & Monica, M. (2025). Design and development of a mobile application for the efficient management and identification of solid waste in North Lima. *International Journal of Engineering Trends and Technology, 73*(1), 54–67.

Babayemi, J. O., Ogundiran, M. B., Weber, R., & Osibanjo, O. (2018). Initial inventory of plastics imports in Nigeria as a basis for more sustainable management policies. *Journal of Health & Pollution, 8*(18). https://doi.org/10.5696/22156-9614-8.18.1

Bakare, W. (2020). Assessment of Solid Waste Management in Nigeria. *International Journal of Research and Scientific Innovation, 7*(6), 244-250.

Bao, X., & Liu, W. (2018). Research on the application of color semantics in the human-computer interaction design of smartphones. *MATEC Web of Conferences, 176*, 04001. https://doi.org/10.1051/matecconf/201817604001

Blair-Early, A., & Zender, M. (2008). User Interface Design Principles for Interaction Design. *Design Issues, 24*(1), 85–107.

Bonino, D., Alizo, M. T. D., Pastrone, C., & Spirito, M. A. (2016). WasteApp: Smarter waste recycling for smart citizens. In *Proceedings of the 2016 International Multidisciplinary Conference on Computer and Energy Science (SpliTech)* (pp. 1-6).((https://www.google.com/search?q=https://doi.org/10.1109/SPLITECH.2016.7555951))

Brooke, J. (1986). SUS—A Quick and Dirty Usability Scale. In P. W. Jordan, B. Thomas, B. A. Weerdmeester, & A. L. McClelland (Eds.), *Usability Evaluation in Industry* (pp. 189-194). Taylor & Francis.

Chalmers, P. A. (2003). The role of cognitive theory in human-computer interface. *Computers in Human Behavior, 19*(5), 593–607.((https://doi.org/10.1016/S0747-5632(02)00086-9))

Erhabor, N. I. (2024). Unveiling the Impact of Environmental Education: Enhancing Waste Segregation Practices Among University Students. *ASRIC Journal of Health Sciences, 1*(1).

Gamtessa, B. C., De Eknamkul, C., & Rermrun, V. (2022). Investigating U.S. residents' acceptance of mobile apps for household recycling: A case study of New Jersey. *Sustainability, 14*(17), 10874. https://doi.org/10.3390/su141710874

He, J., Li, Z., & Liu, H. (2024). Effects of icon color combinations on visual search performance under different cognitive load conditions. *Applied Sciences, 14*(10), 4212. https://doi.org/10.3390/app14104212

Helmefalk, M., & Rosenlund, J. (2018). Hedonic recycling: Using gamification and sensory stimuli to enhance the recycling experience. *EAI Endorsed Transactions on Game-Based Learning, 18*(18).

Human-Computer Interaction: A Review of Usability, Design, and Accessibility Trends. (2025). *Global Trends in Science and Technology, 1*(4), 25-46. https://doi.org/10.70445/gtst.1.4.2025.25-46

Nkwo, M., & Ede, M. O. (2020). Make waste fun again: A gamification approach to recycling. *Proceedings of the 2020 International Conference on Information and Communication Technology and Applications (ICTA)*, 1-7.

Ogunyemi, A. A., et al. (2023). Impact of environmental education on the knowledge and attitude of University of Benin students towards waste segregation. *Qeios*. https://doi.org/10.32388/wraned

Ojewale, O. S., & Owojori, O. J. (2020). An overview of municipal solid waste management in Nigeria. *Journal of Engineering and Environmental Studies*.

Poirel, N., Vidal, C., Magro, L., Pineau, A., & Mellet, E. (2022). Investigating specific color-meaning associations for both positive and negative meanings. *Psychological Research, 86*, 2229–2241. https://doi.org/10.1007/s00426-022-01732-5

Preece, J., Rogers, Y., & Sharp, H. (2002). *Interaction Design: Beyond Human-Computer Interaction*. John Wiley & Sons.

Purbo, Y. S., et al. (2024). User Interface (UI) design waste management application using design thinking method. *CSRID (Computer Science Research and Its Development Journal), 16*(3), 40–56. https://doi.org/10.22303/csrid-.16.3.2024.40-56

Saptaputra, E. H., Bonafix, N., & Araffanda, A. S. (2023). Mobile app as digitalisation of waste sorting management. *IOP Conference Series: Earth and Environmental Science, 1169*(1), 012007. https://doi.org/10.1088/1755-1315/1169/1/012007

Singh, S. (2006). Impact of color on marketing. *Management Decision, 44*(6), 783–789. https://doi.org/10.1108/00251740610673044

Soleh, M., & Maukar, A. L. (2024). Design and development of the SISAKU application prototype using the design thinking method. *KESATRIA: Jurnal Penerapan Sistem Informasi (Komputer & Manajemen), 5*(2), 648-656.

Trash to treasure: Gamification and informed recycling behavior. (2024). *Proceedings of the International Conference on Information Systems*.

Uwadiae, S. E., Nwube, P., & Aluyor, E. O. (2017). Characterization, disposal and management options of municipal solid waste in University of Benin, Benin City, Nigeria. *Nigerian Research Journal of Engineering and Environmental Sciences, 2*(2), 454-463.

Vijayan, V., et al. (2023). E-waste recycling behaviour: An integration of recycling habits into the theory of planned behaviour. *Journal of Cleaner Production, 413*.

Yalwayi, P., et al. (2024). Innovations for Sustainable Plastic Waste Management in Nigeria. *Advanced Journal of Science, Engineering and Technology, 7*(1), 100-110.

Zsarnoczky, M., et al. (2024). Gamification for Enhanced Recycling Engagement in Circular Economies. *In Proceedings of the 15th International Conference on Applied Informatics*, Eger, Hungary.