



Green Savers: Mobile Application Solution for Environmental Conservation and Community Engagement

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Abstract

Litter has become a significant threat affecting human health, wildlife, and ecosystems. But there are very limited IT solutions that are addressed in this regard. Especially on community-driven clean-up activities. There is no dedicated mobile application was found that enables users to create and participate in environmental cleanup activities. Hence that, a mobile application was developed to promote environmental conservation through volunteer-based litter collection events. The primary objectives are to create and join events, and track impact.

A research-based development (RBD) method was used. Starting with the literature review, the strengths and weaknesses of current mobile application solutions designed for environmental conservation efforts were identified. Designed and created a Figma prototype using the findings of literature review and the author's previous experience in the environmental activities. Then collected user feedback through an online survey based on the Figma prototype, and developed a mobile application using Flutter and Firebase based on the user feedback from survey participants. This ensured that the application was designed and developed based on user-centered design (UCD) principles. Core features included are map-based event creation, real-time event-dedicated chat, XP tracking, and Leaderboards.

An Agile development approach was used in the development process. It allowed continuous iteration based on user feedback and testing. The mobile application was tested on both, emulators and physical devices and improvements were made to layout, usability, and design made through an iterative process. Artificial intelligence (AI) tools such as, ChatGPT, GitHub Copilot, and Grammarly, were used to support various phases of the development, testing, error fixing, and documentation.

As a result, a fully functional Green Savers mobile application was developed. The mobile application filled a very important missing part in IT infrastructure by providing facility to community gathering and coordination for environmental conservation efforts. The solution successfully integrated key features such as event creation, real-time communication, progress tracking, and gamification to encourage participation and long-term engagement. The application demonstrated significant potential for real-world impact and scalability.

Keywords/tags (subjects)

Environmental conservation, community engagement, mobile application, mobile application prototype, user-centered design (UCD), research based development (RBD)

Miscellaneous (Confidential information)

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Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
BaaS	Backend-as-a-Service
CRUD	Create, Read, Update and Delete (database operation actions)
CSR	Corporate Social Responsibility
CV	Curriculum Vitae
GDPR	General Data Protection Regulation
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
ICT	Information and Communication Technology
ID	Identification Document
JSON	JavaScript Object Notation
MFA	Multi-Factor Authentication
NGO	Non-Governmental Organization
RBD	Research-Based Development
REST	Representational State Transfer
SDK	Software Development Kit
SDLC	Software Development Lifecycle
UCD	User-Centered Design
UI	User Interface
UX	User Experience
XP	Experience Points

1 Introduction

1.1 Background and Motivation

Environmental pollution, specifically litter gathering in urban areas and even in remote areas, is posing an immense threat to nature, public health and wildlife. In the modern world with increasing urbanisation, events and recreational activities, outdoor areas such as beaches, river bends, canals, leisure parks, camping sites and various nature preserves experience accumulated litter collection over time. Solving the litter accumulation needs people to work together in a coordinated way by organizing cleanup events in a very practical and efficient way.

The conservation of nature has always been an individual energy of the author, driven by a profound appreciation for the environment and a commitment to its protection. Over the long time, the author has effectively taken part in various Corporate Social Responsibility (CSR) activities pointed at nature preservation, such as litter collecting events, tree planting campaigns, and awareness sessions on deforestation and sustainable practices. These encounters have fortified the significance of addressing environmental issues and the requirement for organized structure to encourage such efforts.

While always having a feel to actively contribute to nature preservation, the author realized that there was a significant crevice in existing social apps tending to the issue of community gathering towards nature activities. This realization drove the author to the thought of creating a platform that would join people around shared objectives of environmental preservation.

In spite of the growing global awareness of environmental sustainability, no widely received versatile or social app exists that joins together communities for on-the-ground environmental activity. Almost all the existing mobile apps are centered on individual efforts and education but lack the ability to organize and join individuals towards a common goal, such as cleaning polluted areas, reestablishing green spaces, or preventing further environmental damage. The nonexistence of dedicated platform for collaborative environmental action presents a substantial gap in leveraging technology for real-world impact.

Motivated by this requirement, the author planned the development of a mobile application that bridges this gap by empowering individuals to come together, organize events, and contribute to environmental conservation. The idea is to create a community-driven mobile app where users can create and participate in cleanup events, track their commitments, and engage in sustainable habits. This thesis is a realization of that vision, focusing on the design, development, and evaluation of a mobile application that encourages community engagement in environmental preservation.

1.2 Research Problem and Objectives

Littering has become one of the most visible and increasing environmental challenges around both urban and natural landscapes. Polluted areas keep accumulating waste due to a lack of proper waste disposal methods, limited public awareness, and a lack of coordinated action. While most of the traditional cleanup events end up unsuccessful due to poor coordination, insufficient volunteer participation, and minimal technological support.

The absence of digital infrastructure to facilitate coordination of community-driven activities remains a critical limitation. While there are a few mobile applications that track carbon footprints, provide environmental education, or individual cleanup efforts, almost none offer community-driven tools to assist people in organizing and participating in local conservation events like clean-up drives, litter collection, and tree planting. This absence of use of digital platforms presents a missed opportunity to leverage digital platforms for collective environmental action (Newman et al., 2012).

The core research problem addressed in this study is:

“How can a mobile application that offers a platform for educating, organizing, promoting, and monitoring, effectively encourage community participation in environmental conservation initiatives?”

Some of the existing digital platforms, such as WhatsApp or Facebook, could facilitate simple coordination, but they lack the specific features and environmental context needed to motivate action, monitor impact, or encourage ongoing participation. By incorporating features like event

mapping, volunteer tracking, reward systems, and environmental metric elements that align with gamification and behaviour change strategies used in successful civic tech tools, a targeted platform could increase awareness and participation (Hamari et al., 2014).

In response to this problem, the objectives of this thesis are as follows:

- To determine the functional and non-functional requirements for a mobile application that promotes community involvement and environmental conservation.
- To design and develop a Figma-based interactive prototype of the proposed application and evaluate it through user testing and their feedback.
- To analyze the survey results (user testing and feedback based on the Figma prototype).
- To develop a mobile application based on the survey results and Figma prototype.
- To validate the final application through user testing and carry out a virtual assessment of its effectiveness in enabling collaborative environmental action.

In order to ensure that the finished product meets real community needs and enhance user motivation to participate in environmental activities, research will employ user-centered design concepts and iterative development based on actual user input.

1.3 Research Methodology

Research-Based Development (RBD) methodology was used in this study. This method combines both theoretical-analysis and real-world development of a digital solution. The goal is to design, prototype, and evaluate Green Savers, a mobile application that encourages community-driven environmental conservation through organized events and educational engagement.

The RBD model is highly suitable for developing software solutions where innovation is needed and user input is critical (Koskinen et al., 2011). This method allows for a highly practical, iterative approach to software development, with each stage supported through research and analysis.

This study integrates two well-known methods to make sure the application is both technically feasible and in line with the actual need of its target users. Methods are:

- User-Centered Design (UCD): UCD places user needs, preferences, and usability at the center of the design process (Norman, 2013). This study combines user feedback at multiple stages through surveys, interviews, and prototype evaluations to make certain the app is effective and engaging.
- Agile Software Development: The Agile method supports adaptive planning, rapid development cycles, and continuous feedback, which is especially useful for digital solutions that are educational or community-focused (Beck et al., 2001). Agile techniques make sure the project stays adaptable and have the ability to make changes based on user feedback, particularly during prototype refinement and final app development.

The combined use of RBD, UCD, and Agile supports a flexible yet demanding methodology that supports both academic and practical user-driven design. The UCD approach makes sure that the application is developed with real user needs in mind, while Agile supports continuous development based on user feedback. This hybrid methodology is especially well-suited for the domain of environmental conservation, where motivation, ease of use, and engagement are critical success factors (Hamari et al., 2014).

1.4 Research Process and Phases

This study's research process is organized into a number of interrelated stages that are representative of the Research-Based Development (RBD) methodology as well as the design thinking process (Figure 1).

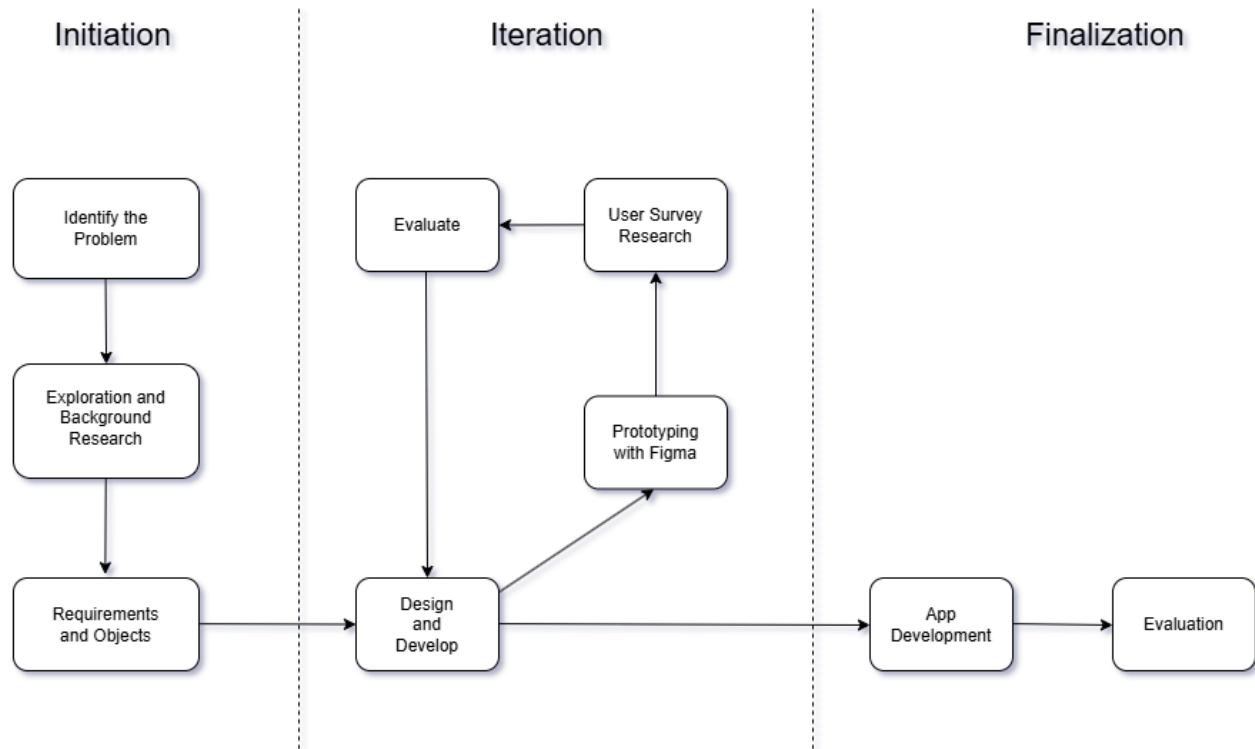


Figure 1. Implementation of the Green Savers App in the Research.

Theoretical research, user involvement, iterative development, and product validation are all balanced in these stages. Each phase helps to gather information in order to build a meaningful digital solution.

Phase 1: Exploration and Background Research

This phase is focused on two aspects. The first aspect is to identify what is considered litter, how it appears, and why it poses a significant environmental threat. This included research on global data on waste management, current litter collection practices, and the financial costs associated with waste management and recycling. Based on these, this section tries to understand the scale and

impact of litter and why it is important to manage litter effectively to protect the natural environment, wildlife, and public health.

In the second aspect, the current state of environmental conservation efforts, community engagement tools, and the existing mobile application solutions available in this domain. A literature review was carried out to identify gaps in existing solutions and the challenges that face communities when trying to collaborate for ecological action. Studies revealed that digital tools can help significantly influence pro-environmental behaviours when aligned with users' motivations and social dynamics (Hamari et al., 2014).

Phase 2: Figma Prototyping Based on Literature Review

In this stage, a high-quality Green Savers Figma prototype was developed based on the literature review. The prototype was equipped with core functionalities such as event creation, interactive maps, volunteer engagement, gamified XP progression, rewards, chat features, and user profiles. This phase helped to convert theoretical ideas into tangible user interfaces. With the author's prior experience in Corporate Social Responsibility (CSR) initiatives, the prototype design was reflected by User-Centered Design (UCD) to reflect potential users' needs and expectations (Norman, 2013).

Phase 3: User Survey Research via Prototype

After developing the prototype, in this stage both qualitative and quantitative methods were used to conduct the user survey. Using the survey, evaluate the usability, aesthetics, and functionality of the prototype. The information gathered during this stage is crucial for iterating and improving the full-scale development of the app where areas are available for improvement. This method guarantees the user expectations and app capabilities are aligned between the user and app, leading to the successful development of the mobile application (Kujala, 2003).

Phase 4: Development of the Mobile Application

To develop a mobile application the Flutter framework is used as the main framework. Based on the feedback received during the prototype testing, Agile methodology was used for iterative and flexibility refinement. Agile's incremental development model is allowed for regular assessment and minor adjustments during the app development cycle (Beck et al., 2001).

Phase 5: Final Validation and Assessment

The final phase involved testing the core features of the mobile application and assessment. Although the app was not deployed publicly due to the study's scope, its potential effectiveness was assessed through the user flow and controlled feedback collection.

2 Literature Review and Knowledge Base

2.1 Understanding Litter and Its Environmental Impact

Litter has become one of the most consistent and visible elements of environmental degradation. Litter causing pollution in land-based and aquatic ecosystems. Not only that, it is causing broader issues such as waste management, public behaviour, and environmental policy. Litter is often perceived as a localized problem. But in reality, it has become a major issue on a global scale, affecting human health, wildlife, water systems, and urban aesthetics.

To understand why community clean-up events are crucial, it is essential to recognize different types of litter, where litter comes from, and how they affect the environment around us. In this section aim at the definition of litter, how polluted areas begin to exist, global trends and data, and the consequences for ecosystems and society. Also, it explores how litter management efforts can be beneficial to both the environment and society.

2.1.1 What is Litter?

According to the Eco Schools website, the simplest definition of litter is, “waste in the wrong place” (Eco Schools, n.d.). It can be any type of object that is discarded improperly in a public or natural environment rather than put in a designated waste collection system. Litter comes in various types of materials, such as plastics, food wrappers, paper products, household waste, industrial waste, and most importantly, cigarette butts, being crowned for most littered object in the world.

Litters are originated from various sources and individuals and divided into two categories as intentional or unintentional. Intentional littering caused by deliberate actions, such as motorists throwing items out of the windows, pedestrians throwing items on the road or sidewalks, or individuals leaving trash in public areas or in natural environments such as camping sites. Unintentional litter is often the results of negligence or poor waste containment. This can be debris that escapes from uncovered trucks, litter escape by wind from overfilled bins, household or commercial waste that is not properly covered, and construction materials that are left exposed. Additionally, wind and wildlife such as birds also disperse waste from unsecured sites and waste bins, further causing environmental litter.

2.1.2 How Polluted Areas Emerged?

Polluted areas emerged due to various factors. These include rapid urban growth, industrial expansion, poor waste management, and social and economic issues. Together, these problems have been led to occur polluted areas, causing degradation of environmental quality in both urban and rural areas. Other reasons when we consider human actions, like lack of environmental education, public awareness, and general carelessness, also contribute to worsening the problem.

Urbanization and Industrialization: Rapid urban growth when mixed up with poor planning always leads to increased pollution levels. In urban areas, surfaces like concrete and asphalt stop water from soaking into the ground. This causes more water runoff, which carries litter into rivers and lakes (Fletcher et al., 2013). In addition, factories, especially in developing countries, often work without strict environmental rules and policies. This is leading them to release harmful waste directly into the environment.

Poor Waste Management: Poor waste collection and disposal systems play a major role in causing pollution in public areas and nature. In many cities, often in developing countries, trash is often thrown in open spaces, on roadsides, or into water streams. This usually happens due to poor waste management infrastructure, poor enforcement rules, or lack of environmental awareness. Additionally, some people see littering as a normal habit and feel no compassion to change, contributing significantly to environmental degradation (DAWN.COM, 2017).

Agricultural Practices: Agricultural runoff is another major issue of water pollution, especially in rural areas. Due to excess usage of fertilizer and pesticides adds extra harmful substances to the runoff water, which eventually ends up in rivers or lakes. This phenomenon is known as eutrophication, which force negative effects on aquatic biodiversity and water quality (Carpenter et al., 1998).

Socio-Economic Factors: Social and economic factors also contribute to the uneven distribution of pollution. Poor and marginalized communities often live in polluted areas like landfills, factories, or open drains because of cheaper lands or limited housing options in well-civilized areas. Often these communities have less political influence or power to demand cleaner and safer living infrastructure, forcing ongoing environmental injustice (Bullard, 2000).

2.1.3 Consequences of Litter

Litter has unimaginable consequences far beyond unpleasant visuals to the eyes. First, it may appear just as a local issue, but over time, it threatens environmental stability, human health, wildlife, economic systems, and community wellbeing. These impacts apply in both the immediate and long-term affecting ecosystems and societies globally. This section describes consequences of litter on various segments.

Environmental Degradation and Long-Term Environmental Damage: Litter plays a major role in the deterioration of natural lands. It contaminates all the matter states, which are soil, air, and water, introducing toxic and non-biodegradable materials into ecosystems. Some materials, like plastic and synthetic waste, have extremely low breakdown characteristics, releasing microplastics and chemicals that change the natural balance of the environment (Jambeck et al., 2015). Eventually this is leading to reduce the quality of soil and fertility, reduce biodiversity, alter natural cycles, and contribute to climate change through greenhouse gas emissions from decomposing waste.

Health & Safety Concerns: Incorrectly thrown waste like broken glass and rusted metal easily can cause physical injuries to humans. Food waste and open garbage attracts disease-spreading animals such as rats and mosquitos. Public exposure to waste can also increase the risk of respiratory and gastrointestinal diseases.

Water Pollution: One of the most serious consequences of litter is the pollution of valuable water resources. Litter always finds its way into storm drains, canals, rivers, lakes and oceans. While they are in the water, they can release harmful chemicals and also block waterways. Ultimately, this is leading to disturbing aquatic life and reducing the quality of drinking water sources (Carpenter et al., 1998). In many lowland cities, flooding is amplified by clogged drainage systems caused by litter gathering.

Aesthetic Impact: Presenting litter is easily degrading the visual appeal in urban and natural environments. When waste is covered in places such as parks, beaches, public streets, and natural environments loses its attractiveness causing discouragement of both local engagement and

tourism. When cities, towns, and natural places fail to maintain a clean environment they may experience a reduced number of visitors and damage their public image.

Economic Cost: Managing litter is a substantial cost for governments and municipalities all over the world. These costs can be for street cleaning, waste collection, landfill maintenance, and also pollution control programs. When litter exists, business also affected due to people keeping away from dirty areas and harming their reputation. According to the World Bank (2018), the global cost of solid waste management is expected to exceed \$375 billion annually by 2025.

Wildlife and Ecosystem Harm: Litter is causing catastrophic damage to wildlife. Animals often mistake waste for food and consume it. Sea turtles often mistake polythene bags for jelly fish and birds mistaken little plastic objects for insects, leading them to the ingestion of non-digestible materials, causing shocking, internal injuries or death. Small animals often get stuck inside bottles or jars, eventually dying due to starvation. Marine mammals like whales and dolphins frequently die by entanglement in abandoned fish nets. Birds, wildlife, and aquatic animals frequently become entangled in plastic waste, and leading to restricted movement which can be fatal.

Community and Social Impact: Communities surrounded by litter always lead to poor quality of life. Environments like this may cause people to feel less proud of the area they live in and more neglected, leading them to behave like vandalism and more littering. People living in these conditions are more likely to expose health and environmental risks.

2.1.4 Environmental and Social Benefits of Litter Management

The excellent litter management strategies bring many benefits for the environment, society, and economy. Even though litter is often viewed as harm and degradation, actions like prevention, cleanup, recycling, and involving the public can create positive outcomes for both ecosystems and societies. These benefits not only help current challenges but also support a cleaner and more sustainable future. The following domains demonstrate the benefits of proper litter management.

Improved Local Environments and Community Wellbeing: Proper litter management provides a cleaner environment and suitable liveability of public spaces while helping to maintain physical and mental wellbeing of local communities. Also, clean neighbourhoods create stronger bonds

between wellbeing and nature, leading to greater civic pride and anti-social behaviours. When residents see their environment is clean, they often foster their own responsibility toward nature preservation and volunteer participation in such events.

Boosted Tourism and Recreation Appeal: Cleaner destinations such as beaches, parks, camping sites, streets, rivers, lakes, and scenic sites always attract outdoor enthusiasts and tourists. It boosts their positive mentality and experience and helps likelihood to return. Studies have proven that increased litter on beaches lead to attracting less tourists over the time, adversely affecting local economies (NOAA Marine Debris Programme, 2024). Vice versa, well maintained environments attract more visitors, boosting local economies.

Strengthened Support for Environmental Conservation: Achieving goals becomes effortless for environmental protection groups when they apply proper waste management methods and rules and policies. For instance, community-led reforestation projects and litter collection projects have become success restoring the ecosystem and clean environments. Also, these events are providing educational opportunities at the same time about environmental stewardship.

Economic Gain for Local Businesses: As mentioned above, clean public places attract more customers and enhance the reputation of commercial cities. With that, local businesses gain benefits from litter-free environments and lead positive shopping, dining and experience atmospheres. Businesses also benefit from reduced waste disposal costs and can gain brand image recognition by participating in or sponsoring environment-related activities (World Bank, 2018).

Reduced Financial Cost for Municipalities and Governments: Municipalities and governments are able to save financial costs significantly from better litter management processes through lowered maintenance costs for cleanups and reduced infrastructure damage caused by waste-related blockages (Environmental Protection Agency, 2023). Therefore, governments and municipalities can prioritize financial costs and resources on other development projects and long-term investments.

Increased Volunteers and Participants: Public clean-up events, recycling campaigns, and environmental awareness programs mostly rely on volunteer participants, students, military

forces, NGOs, CSR-aligned organizations, and even entire families. These activities foster a sense of community and environmental responsibility among participants. Furthermore, involvement in these events increases awareness of environmental issues and leads to adopting sustainable behaviours (Hartley et al., 2015).

Protection of Water Sources: Effective litter management methods play a major role in protecting both surface and underground water resources. In the absence of proper litter management strategies, pollutants degrade water quality, threaten aquatic life, and reduce the availability of the safe drinking water.

By implementing proper waste disposal systems, conducting litter clean-up events near waterways, and educating the public regarding pollution prevention, communities can protect their water sources. These actions eventually lead to help protect and maintain water quality for drinking, agriculture, recreation, and ecosystem services, aligning with Sustainable Development Goal 6, which is Clean Water and Sanitation, set by the United Nations (United Nations, n.d.).

Wildlife and Ecosystem Stability: Since litter poses a significant threat to wildlife such as ingestion, exposure to toxins, and entanglement in waste materials, eventually leading to injuries or deaths. Restoring litter and toxic-free habitats supports biodiversity and enables balanced, safer, and natural ecological processes to recover and protect animal populations more effectively.

Long-Term Benefits for Future Generations: Preventing pollution and managing litter properly secures a healthier and cleaner environment for future generations. Not only that, it ensures the preservation of natural resources and ecosystems. Educating the younger generation regarding the importance of waste reduction and proper waste management lays a strong foundation for the future (UNEP, 2021).

Contribution to Global Environment Goals: Reducing litter and proper waste management helps fight climate changes by decreasing pollution and preserving resources. These efforts also support United Nations Sustainable Development Goals, particularly Goals 11, 12 and 14, which are Sustainable Cities and Communities, Responsible Consumption and Production, and Life Below Water, respectively.

2.2 Mobile Applications for Environmental Conservation

In recent years, a handful of mobile applications have emerged to support environmental conservation. These applications are equipped with various functions, such as litter collect individually, environmental education, real-time litter tracking, and even donations for environmental conservation organizations. These apps provide portability and accessibility, making them a unique advantage in mobilizing communities toward eco-conscious behaviour.

However, most of these applications focused on individual tasks, such as carbon tracking, recycling tips, or reporting pollution in various places, rather than community-driven engagement as a team effort. For instance, tools like Litterati, allow users to photograph and tag litter to build a global database but lacks the ability to foster long-term collaboration or gamified community actions (Glaros, 2019). Similarly, the Clean Swell tool is entirely focused on oceanic conservation and individual litter cleanup efforts.

Currently, almost all the apps lack support for community-driven events towards a single goal at a time. Not only that they also lack in-app communication and group-coordination tools such as chat features. The absence of a chat feature makes it difficult for organizers to share information, gather opinions of other users, or build long-term community engagement. Studies have proven that the environmental behaviour change is more effective when it is reinforced by social gatherings, common community goals, and shared accountability (Hamari et al., 2014).

The below table 1, presents a feature comparison of proposed Green Savers application and four existing environmental cleanup apps: Litterati, Clean Swell, CleanUp, and Ploggit.

Table 1. Comparison of Features Between Green Savers and Existing Apps

Feature	App Name	Green Savers	Litterati	Clean Swell	CleanUp	Ploggit
Create and join cleanup events		Yes	No	No	Yes	Yes
Volunteer hours		Yes	Yes	No	No	Yes
Track user participation		Yes	Yes	No	No	Yes
Calendar Integration		Yes	No	No	No	No
User milestones and badges		Yes	No	Yes	Yes	No
Real-time map integration		Yes	No	Partial	No	Partial
Leaderboard (XP based)		Yes	No	No	No	No
Chat feature		Yes	No	No	No	No
Data collection and submission		Yes	Yes	Yes	Yes	Yes
Environmental news and awareness content		Yes	No	Partial	No	No
Partnered with environmental organizations		Planned	Yes	Yes	Yes	Yes
Reward certificate for event participation		Planned	No	No	No	No

This project is not only aimed at creating and participating in environmental actions but also addressing these missing features in present solutions to build a stronger, mission-driven community.

2.3 Community Engagement in Environmental Cleanup Activities

The most efficient way to address an environmental challenge is to gather the community together towards one goal, such as a litter collection event, tree plantation, or awareness campaign. This has been proven to building sense of responsibility and environmental stewardship within communities (Measham & Barnett, 2008). While supporting keeping a cleaner surroundings, these events promote long-term behavioural change through active participation.

Previous studies show that individuals are becoming pro-environmental characters when they are occupied in socially supported initiatives. And the social identity theory suggests that people gain more motivation when they are mixed up with groups that have shared values and goals (Tajfel &

Turner, 1986). Environmental cleanup events help community members to work together, get to know each other, and support shared values around environmental conservation.

However, organizing such events usually has challenges such as coordination, volunteer transportation, and exchanging information. Büscher et al. (2020) show that using digital platforms can streamline these challenges, providing more facility to enable better communication, planning, and participant engagement. But still, most of community based environmental activities depend on offline methods or usual mobile applications, such as Facebook or WhatsApp, which are not specifically designed to these kinds of events to organize or track environmental impact. With this growing litter issue, there is a truly important and requirement for digital tools that are specifically designed to address these challenges.

2.4 Software Development Life Cycle (SDLC) for Mobile Apps

The Software Development Life Cycle (SDLC) is one of the major software development methods widely used. This method clearly defines the structure and the phases of the development of a software product (Jain, 2011). There are many variations of the software development life cycle is presented to address at different levels of requirements. This study was carried out using 5 of the main elements of the SDLC:

1. Identify and gather requirements
2. Design and prototyping
3. Development
4. Testing
5. Review

For mobile applications, SDLC models maintain an organized approach to satisfy the user expectations and changing market demands while guaranteeing quality, usability, and performance (Pressman & Maxim, 2020).

In this study, Agile methodology was used because it leaves a lot more room for iterative and incremental development of the product whenever arise of change in requirements.

2.5 Usability and User-Centered Design (UCD) Principles

The Usability and the User-Centered Design (UCD) are fundamental methods in developing software equipped with qualities such as, intuitive, efficient, and satisfying to use. Usability refers to how easy it is the application to interact without having any difficulties or confusions. For users without having any technological knowledge backgrounds or giving at any age group, it provides clear navigations, minimal cognitive load, and responsive feedback to users to go through and perform tasks without frustration or excessive training.

The User-Centered Design is a framework that places the user at the top of the hierarchy of the design and development process. In this method, instead of assuming what the user wants, the user is actually involved in continuous observation, feedback sessions, usability tests, and iterative design adjustments of the product.

In the foundational study by Gould and Lewis (1985) highlighted three key principles of UCD:

1. Early focus on users and tasks – understanding users and their requirements
2. Empirical measurement – gather actual user feedback through usability testing to guide design decisions
3. Iterative design – continuous refining of the product through repeated cycles based on user feedback

In the development of the Green Savers app, UCD played a major role to make sure that the application is equipped with features and functions to serve its purpose. The process included developing a Figma prototype and collecting user feedback based on that prototype, then refining the app based on that participant feedback. Ultimately, ensuring that both interfaces and features are aligned with user motivations and habits (Norman, 2013; Gould & Lewis, 1985).

2.6 Tools and Technologies Used

When developing a mobile application, required careful selection of suitable tools and technologies in order to streamline development, enhance functionality, and ensure scalability given at any time. The following key tools were used in the development of the Green Savers mobile application.

2.6.1 Figma for Prototyping

The Figma tool was used as the primary tool for designing the application prototype of the Green Savers application. Tool enabled to create a high-fidelity prototype with user flows, screen transitions, and interface elements such as buttons, icons and forms. In this study author used a cloud-based version of Figma that supports real-time collaboration. The main advantage used of this cloud-based version is having access to the live prototype for users to provide feedback in the survey research.

2.6.2 Flutter for Cross-Platform Development

Flutter is an open-source UI Software Development Kit (SDK) developed by Google for building natively compiled applications for multiple platforms such as mobile, web, and desktop using a single codebase. The Flutter uses the Dart programming language and allows convenient features like hot reload, a reactive framework, and customizable widgets. In this study using Flutter enabled efficient development for both Android and iOS platforms with consistent design and performance (You, 2021).

2.6.3 Google Maps for API for Location-Based Features

The Google Maps API is used for mapping capabilities and capturing geolocation and reversed-geolocation services to enhance the usability of location-based applications. In the Green Savers app with Google Maps, users are able to locate cleanup sites, search locations, and pinpoint locations in event creation. The integration of map-based interaction improved event discovery and planning within the app for users.

2.6.4 Firebase for Data Storage and Authentication

Firebase is a Backend-as-a-Service (BaaS) platform developed by Google. This platform offers tools for app development, such as a real-time database, authentication, cloud functions, and analytics. In the app, it was mainly used for managing user data, storing event information in real time, and authenticating users securely. Firebase is also supports seamless scalability and reduced backend development time (Moroney, 2017).

2.7 Security Considerations and Best Practices in Mobile Applications

In the present, incorporating robust security features into the development of mobile applications are extremely important. Especially those that manage personal user information, track location, and involve community gathering. Maintaining of user data properly, accessibility, confidentiality, and integrity promotes trust. Not only that, it supports user retention and brings the application into compliance with global data protection laws such as the Global Data Protection Regulation (GDPR).

Nowadays, mobile applications are heavily relying on cloud services and third-party APIs. This imposes vulnerabilities on both client and server sides. Therefore, this section discusses the critical role of security in mobile applications, platforms, and the technologies used in this project. In addition to protecting user data, and the application's strong security features guarantee the credibility and sustainability of its environmental and social missions.

2.7.1 Importance of Security in Mobile Applications

Almost most of the mobile applications these days process and store sensitive user information. Especially in mobile applications aimed at environmental conservation can include personal identification details, volunteered location data, and participate records in events. If any kind of unauthorized access to these data can lead to privacy violations, identity misuse, and eventually declining of user confidence and application integrity as well.

Furthermore, gamification features like experience points (XP), milestones, or badges are useful for enhancing the user engagement, these also introduce possible misuses by dishonest individuals looking to falsify accomplishments. Since then, implementing proper security and validation mechanisms throughout the application is very important to safeguard user data and preserve the authenticity and integrity of the environmental conservation efforts.

In the study by Layode et al. (2024) highlights the importance of growing challenges of protecting sensitive environmental data. The study strongly highlights that the following strong privacy rules like GDPR is essential for building user trust. Also, study explain that designing and developing apps always needs to follow privacy concerns in mind from the start to end to make sure of using

proper methods for data safeguarding. Eventually, these practices ensure that sensitive information is handled responsibly in environmental projects and mobile applications.

2.7.2 Security Features Offered by Flutter and Dart (Frontend)

In the Flutter framework, the Dart acts as the programming language and comes with many security-related advantages for mobile application development. Since Dart compiles to native machine code, it is more challenging to reverse engineer compared to other interpreted languages like Kotlin and Java. Moreover, during the build process, Flutter supports code obfuscation. With that, Flutter helps to protect sensitive logics and intellectual properties within the application. Even though Flutter has robust security features, it is always up to developers to adopt secure coding practices to minimize risks such as insecure data storage or weak input validations.

2.7.3 Security Features Provided by Firebase (Backend)

For backend services in mobile applications, Firebase supports a comprehensive set of security features to protect user data. One of the core functionalities of it is Firebase Authentication, which offers a secure method to verify user identity through multiple providers such as email/password, phone number, Google login and Facebook login. Firebase also supports Multi-Factor Authentication (MFA) for more robust account security (Firebase, n.d.).

For data access control, Firebase allows developers to apply custom security rules. With that facility, developers are able to give limited or full access based on specific authentication states or request parameters for access data stored in services like Firestore and Realtime Database (Firebase, n.d.).

When transmitting data between client applications and servers, Firebase encrypts all the data in transit using HTTPS. This Data Encryption is one of the key features in the Firebase security model.

Firebase also offers the App Check feature, which means Firebase always verifies that the incoming request is originated from an authenticated and verified instance of the app. To achieve this, Firebase uses verification providers such as SafetyNet for the Android platform and

DeviceCheck for iOS platform. If the attempt fails at any given moment, Firebase flags attempts as unauthorized sources or bots and then blocks the incoming traffic (Firebase, 2021).

With those layered security features, Firebase assures that it provides robust protection for mobile applications, reducing risks of unauthorized access, data breaches, and abuse of backend services.

2.7.4 Platform-Level Security From Google Play Store and Apple Apps Store

Official platforms like Google's Play Store and Apple's Apps Store provide a set of security methods to maintain both user's protection and platform integrity, and reputation.

Google Play Store Security Measures:

- **Google Play Protect:** This is a built-in malware protection system provided by Google services. This service scans apps before and after installation to detect any harmful behaviours. This service uses machine learning and automatically detects and disables or removes any malicious apps from users' devices (Google, n.d.).
- **Play Integrity API:** This API helps developers to assess the app integrity and identify that requests are coming from devices that are genuine and unmodified sources.
- **App Signing by Google Play:** Google helps developers to keep their app signing keys safe by managing them securely. This reduces the risk of keys getting stolen or misused (Google, n.d.).

Apple App Store Security Measures:

- **App Review Process:** Every app submitted to the App Store undergoes thorough review to ensure that the app is in compliance with Apple's guidelines on privacy, security, and content. This process prevents the distribution of malicious or inappropriate apps even before reaching the end users (Apple, n.d.).
- **App Store Privacy Labels:** When an app displays on Apps Store, every app is required to provide detailed information about their apps data collection and usage practices. This is very useful for users who are concerned about their privacy seriously.

- **Code Signing and Notarization:** Every app distributed through App Store has to be signed with a valid Apple-issues certificate, this way app's source is verified. Additionally, Apple also has an app scan method to identify if an app contains malicious content before distribution.

With these platform security features, both developers and users can enhance the trustworthiness and transparency of the apps and platform, ensuring protection of user data and compliance with industry standards and regulations.

2.7.5 Best Practices for Secure App Development

When developing mobile applications, it is vital to integrate robust security measurements throughout the software development lifecycle. Implementing industry leading security techniques not only protect user's sensitive data it also enhances application reliability and trustworthiness. Some of the industry leading security concerns are,

- **Secure Coding Practices:** When writing codes, it is vital to align the codes with secure coding standards. This will reduce the risk of injection attacks, buffer overflows, and improper error handling. Developers must follow established guidelines and regularly update their knowledge to address emerging threats (Kudriavtseva & Gadyatskaya, 2022).
- **Authentication and Authorization:** Implementing a strong authentication system, including multi-factor authentication, ensures that only authorized and registered users can access the application. Proper session management and role-based access to app features will ensure security by restricting user privileges appropriately (Peruma et al., 2024).
- **Data Encryption:** It is very important to encrypt sensitive data in the app at rest and when transmitting over the internet. With strong encryption algorithms, it will be difficult for unauthorized access and data breaches. Using strong encryption methods and secure key management is essential for maintaining data confidentiality and integrity (Kudriavtseva & Gadyatskaya, 2022).
- **User Privacy and Data Minimization:** Having user trust towards an app is very important. Developers must always maintain a transparency and privacy policy when collecting user data. Also, should only collect necessary user data for the app requirements.

- **Regular Security Testing:** Developers need to and must conduct both static and dynamic analysis in development process for security assessments. This will help to identify vulnerabilities early in the development.
- **Secure Third-Party Integrations:** Developers must always try to use native framework packages. This will reduce the app compatibility and it will make apps future-proof and also mitigate the vulnerabilities of exposing the app structure. Introducing third-party libraries and APIs can pose a risk throughout the application. Therefore, evaluating and monitoring third-party libraries, packages, and APIs is very crucial (Jacobs & Coetzee, 2023).

3 Prototype Development and Research

3.1 Figma Prototype Design

The Figma UI design tool was used to create the prototype of the Green Savers mobile application. For this stage the author utilized prior experience, theoretical findings, assumptions of community user expectations, and environmental goals in an interactive design. Mainly the Figma tool was selected due to its cloud-based environment, quick feedback cycles, and ability to create interactive user journeys without using any extensive programming knowledge (Gibbs, 2019).

3.1.1 Purpose of the Prototype

The primary objective is to create the prototype to understand how users would interact with the app in a real-world scenario. Creating a prototype offers few advantages over creating a functional app without having any cost. Some of the advantages are effectiveness of usability, visual hierarchy, and interface logic (Preece, Rogers, & Sharp, 2015). It provides user feedback to validate design assumptions before implementing full-scale application, saving time, cost, and complexity.

3.1.2 Core Features included in the Prototype

The prototype was designed based on observations gained through the authors firsthand experience, academic study, and real-world community requirements. Some of the core features in the prototype are:

- **Event Creation and Browsing:** A well-structured form to create events and display in the upcoming events feed in a card style.
- **Mock Map Integration:** Using static Google Maps to mimic real-life, like real-time location selection.
- **User Profile and Achievements:** Volunteer hours, green friends, events of joined/created, and achievements.
- **Community Chat System:** An event-based and individual chat system to enhance and foster community bonds.
- **Eco-News Feed:** News related to environmental conservation and efforts.
- **Education Feed:** Educational and sustainable tips to be aware and practice.

- Custom Setting Panel: Measurement units, language preferences, and profile settings.
- Gamified Progression System: Experience points system, badges, rewards and milestone achievements to encourage consistent engagement.
- Global Leaderboard: Ranked volunteers based on experience points (XP) to display community recognition.
- Notification Panel: To prompt users about newly created events, news, upcoming events and completed events.
- Login/Profile Creation: Initial screen of user login and profile creation.

3.1.3 User Flow and Navigation (App Prototype)

For any application, user flow and navigation play a crucial part, as users expect to intuitively explore the app and complete tasks with minimal effort. The user flow is how users move from one screen to another to complete tasks such as view an event, join a cleanup mission, or chat with other volunteers.

User Flow Design: The user flow of app prototype (Figure 2) begins with an onboarding screen. Then leads users through login or account creation screens, followed by the home screen. The app is using a bottom navigation bar to provide access to 5 primary screens: Home, Global News, Create Event, Knowledge Center, and Notification Panel. Apart from that side drawer is included to access important but less frequent features such as account settings, leaderboard, calendar, and more. A visual representation of these screens is provided in Section 3.1.6 Prototype Interface Design.

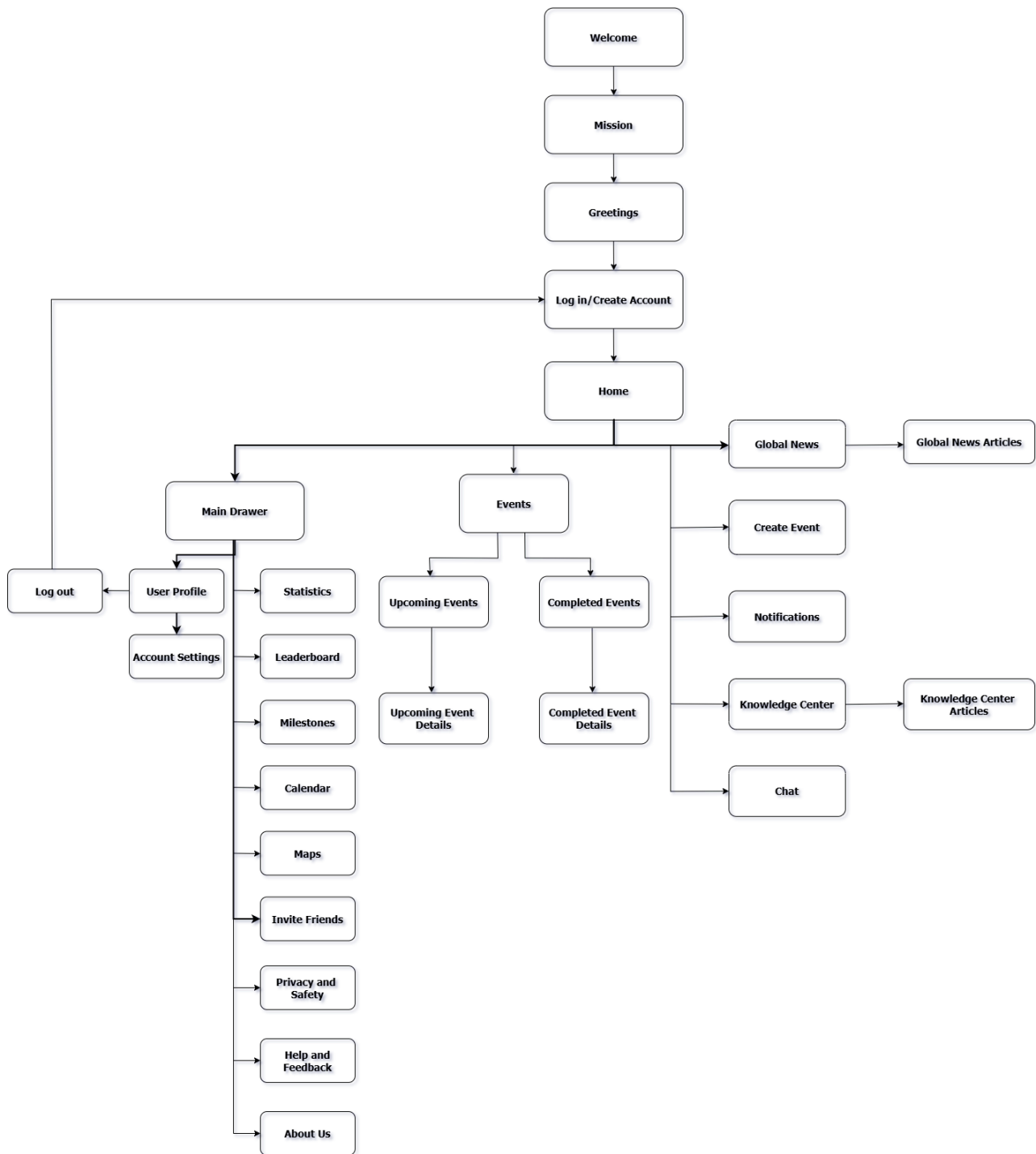


Figure 2. User flow of the Green Savers app prototype.

When planning the app, the author carefully designed each action to require no more than 3 steps to complete from the home screen, following best practices in UX to reduce friction and drop-off (Babich, 2017).

3.1.4 UI/UX Considerations

Attentive User Interface (UI) and User Experience (UX) design are very important for a mobile application to have aesthetically appealing and functionally accessible to different user bases. This section focuses on visual choices in UI and UX strategies used in the prototype.

UI Design Choices: The author wanted to express the visual language of the Green Savers app while reflecting an eco-conscious mission. Therefore, the green color and sub-variation of the green color were chosen as the app theme to dominate throughout the entire app. Not only does that green color represent the application theme and vision, but also green is scientifically shown to be the most restful color for the human eye. Using green color reduces eye strain during extended use (Lidwell et al., 2010). The author chose minimalistic icons for a friendly visual appearance, and typography was selected for clarity and responsiveness across screen sizes.

UX Principles Applied: From a UX perspective, the app is designed to achieve user goals easily and intuitively, even without instructions. Users are able to perform functions such as finding a location, joining or creating events, and other core actions with ease. Touch-friendly design was focused on when implementing icon size, button size, and sufficient padding to align with mobile application guidelines. Consistent colors, icon placement, and clear layout allowed users to build muscle memory as they navigated through the app. Feedback mechanisms such as page loading and form validation messages were added to avoid user confusion.

3.1.5 Prototype's Role in Research

This prototype played a major role in the research. All the user surveys, interviews, and usability testing were carried out based on this prototype. Survey participants were able to interact with the app in a near-realistic background, ultimately leading to understanding and identifying missing features, weaknesses, limitations, strength, and validating the app's feature set. This part will be discussed deeply in the survey section in upcoming chapters. Kujala (2003) highlighted that usability tests should be based on real-life content, and this almost realistic prototype model supported that idea.

3.1.6 Prototype Interface Design Breakdown

The following screen captures represent the main features and interfaces of the app prototype, showcasing essential functionalities and user interactions.

The onboarding screen introduces new users to the app's mission and goals with a friendly welcome flow (Figure 3).

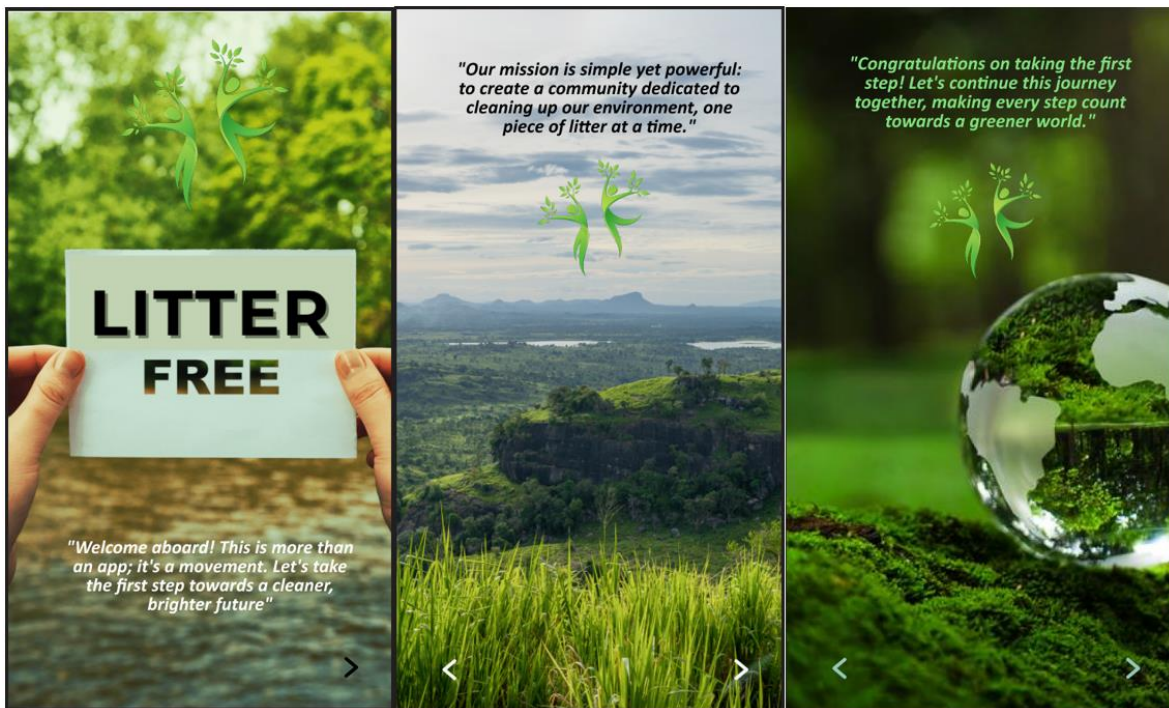


Figure 3. User Onboarding Screens.

The login and account creation screens allow users to securely access or register their accounts (Figure 4).

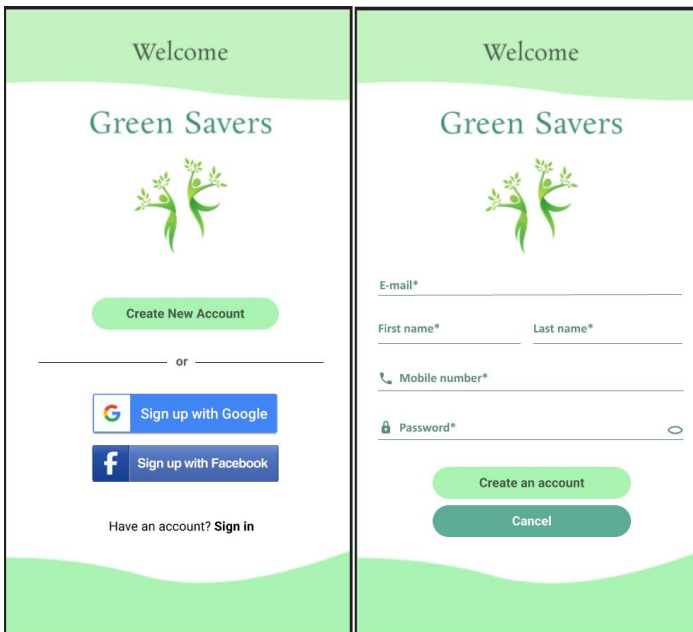


Figure 4. Login and Account Creation Screens.

The home screen and main drawer provide navigation access to core features and user sections (Figure 5).

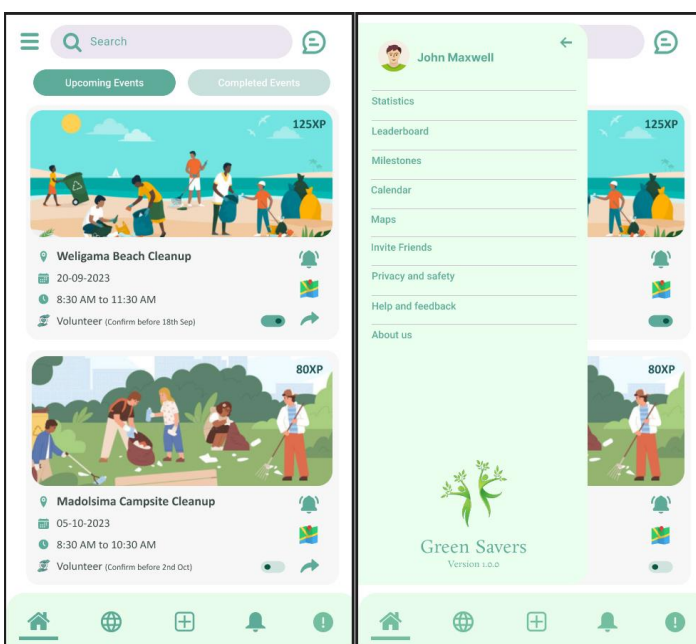


Figure 5. Home and Main Drawer Screens.

The account statistics and settings screens display user achievements and allow profile customization (Figure 6).

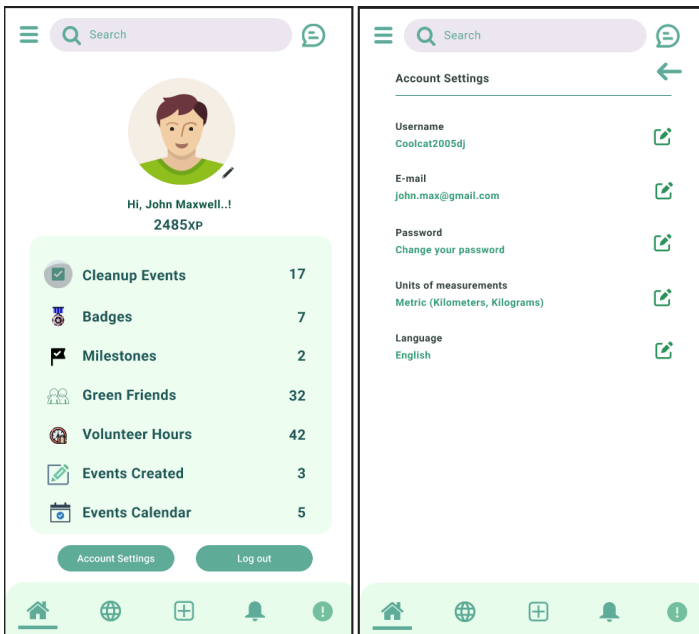


Figure 6. Account Statistics and Account Settings Screens.

The event creation and chat screens enable users to organize cleanup events and communicate in real time (Figure 7).

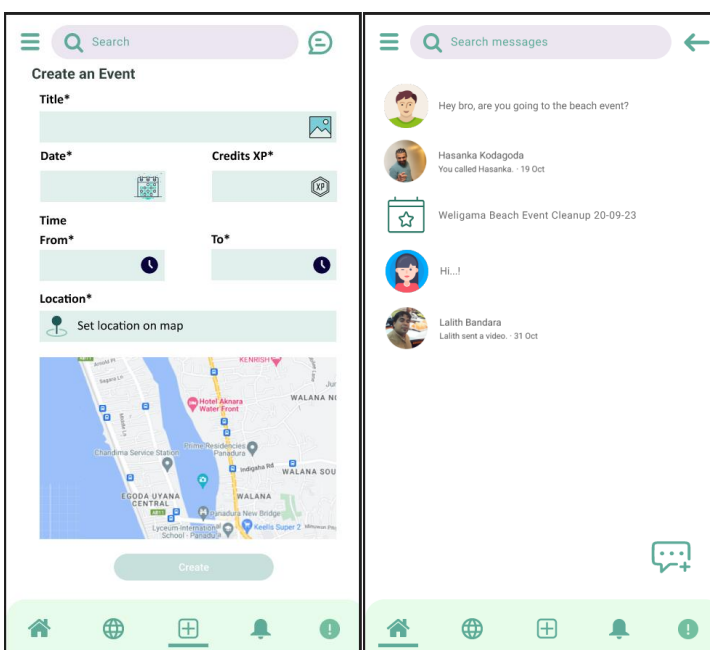


Figure 7. Create an Event and Chat Screens.

The upcoming events list and summary screens display scheduled events and their key details (Figure 8).

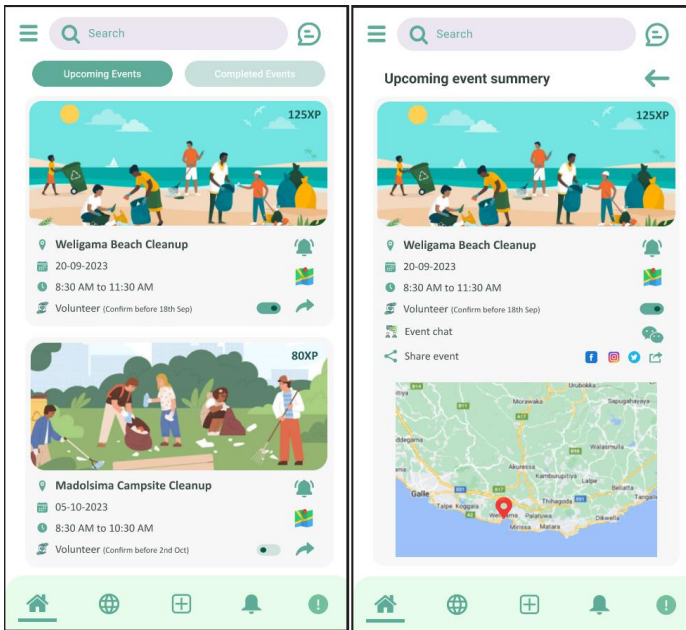


Figure 8. Upcoming Event List and Upcoming Event Summary Screens.

The completed events list and summary screens showcase past events along with results and participation info (Figure 9).

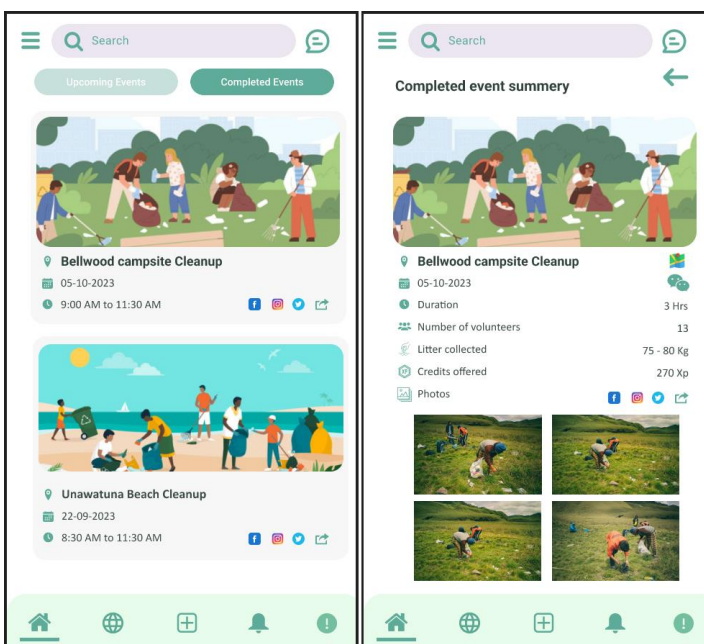


Figure 9. Completed Events List and Completed Event Summary Screens.

The statistics, leaderboard, and milestones screens highlight the app’s positive environmental achievements at a global scale, display a local users leaderboard based on country-based, and individual achievements through gamified engagement elements (Figure 10).

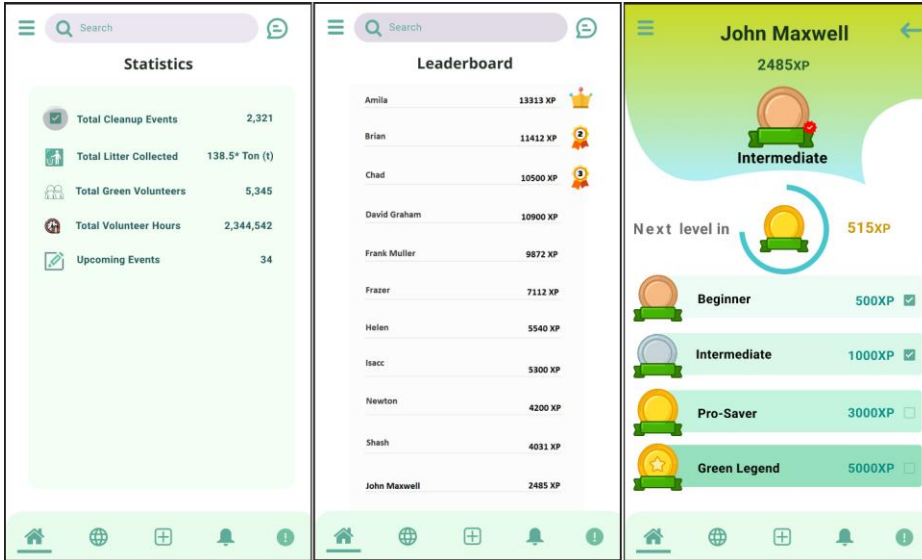


Figure 10. Statistics, Leaderboard, and Milestones Screens.

The calendar, map, and invite screens provide a detailed lookahead before scheduling an event or participating an event, enabling search for locations and location selection, and viewing existing app users who are already using the app and, if not, expanding the user base by sending an invitation (Figure 11).

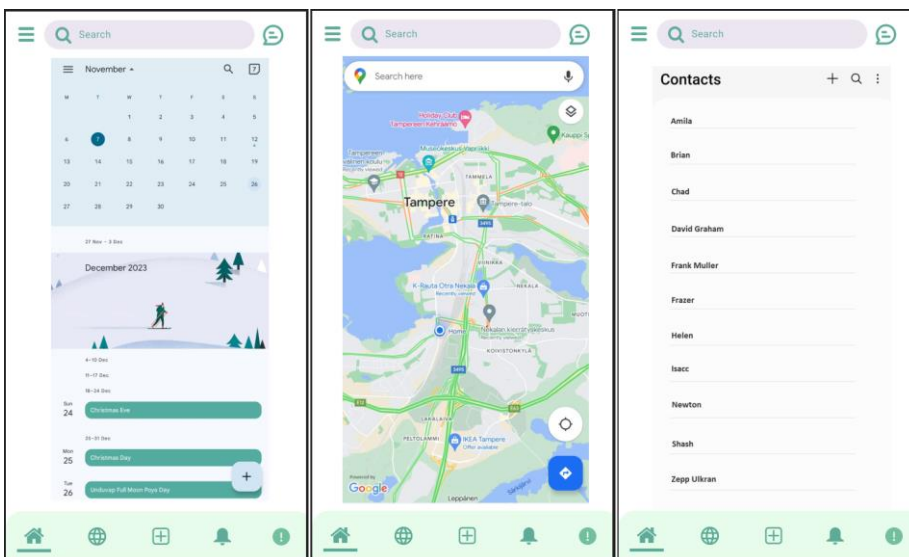


Figure 11. Calendar, Map, and Contacts Screens.

The global news list screen displays environmental news articles with a detailed view for each article (Figure 12).

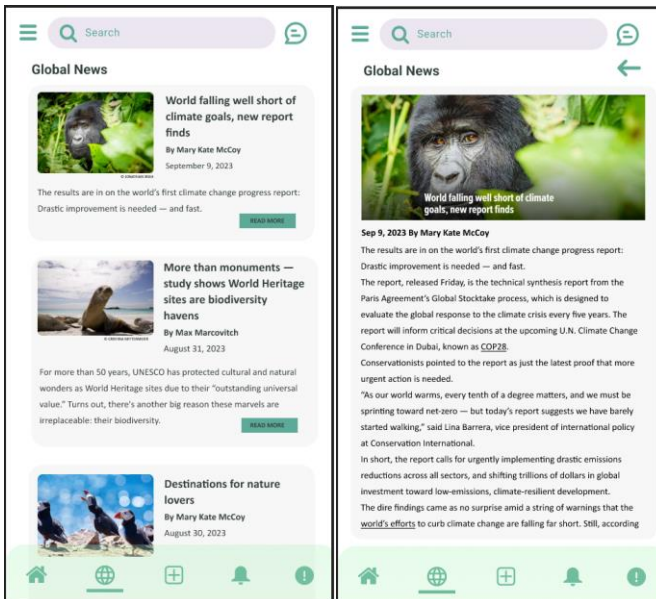


Figure 12. Global News List and Detailed News Screens.

The knowledge and action center screen provides learning resources and environmental awareness content (Figure 13).

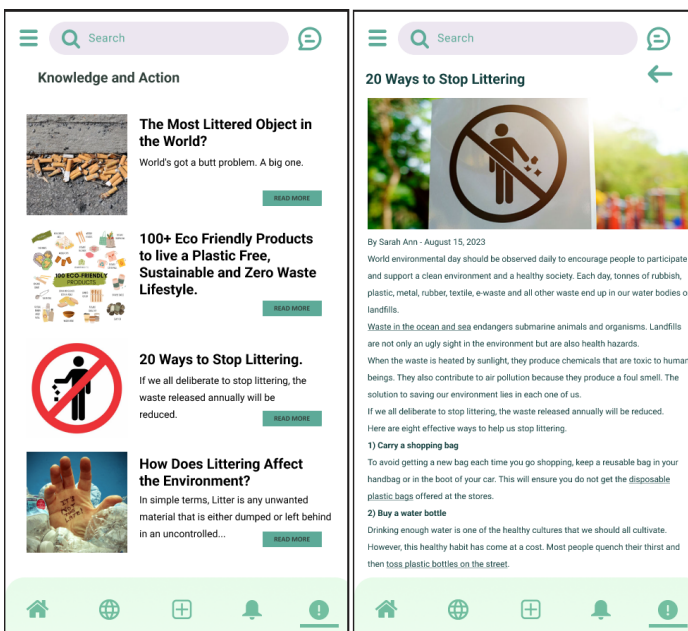


Figure 13. Knowledge and Action Center and Detailed Article Screens.

The notification panel screen shows app alerts and updates for user engagement and reminders (Figure 14).

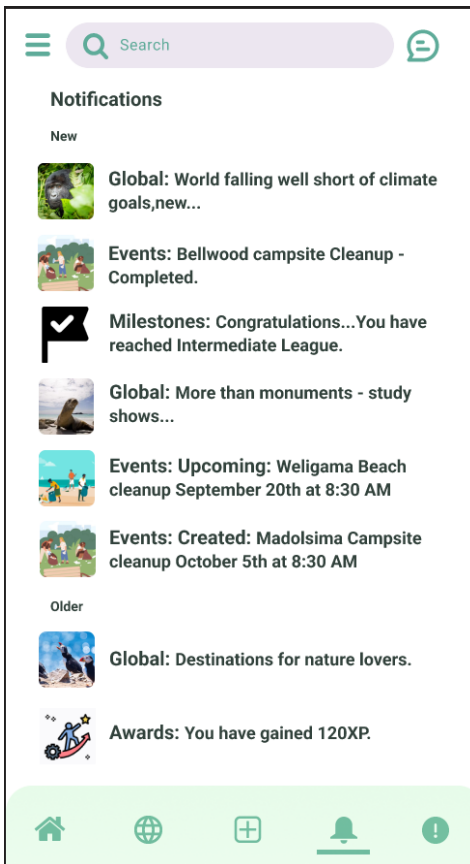


Figure 14. Notification Panel Screen.

3.2 Data Collection and User Research

To validate the concept, usability and the relevance to users, the Green Savers mobile application prototype concept was used in this user research. This involved carefully designing and selecting appropriate questions to conduct the online survey. The survey was targeted at a diverse group of users who could be potential users of the app. These participants included IT professionals who have experience with UX/UI design, QA engineers who could offer insights of the app usability and functionality. Mainly, was able to get some input from professional environmentalists regarding user needs and environmental requirements of a particular mobile solution. Ultimately, the author wanted to gather well-rounded feedback on environmental engagement, app usability, and design improvements for mobile applications dedicated to environmental conservation to make sure that the final product is of the highest quality as any user expects.

All the participants were first invited to interact with the high-fidelity app prototype of the Green Savers app developed using Figma tool. Then participants were requested to answer well-structured questionnaires to evaluate various areas such as user experience, content relevance, app design, user relevance to the field, and ultimately potential improvements.

All the data collected from the survey was secured and stored in a confidential remote host and strictly used for this academic purpose only. All the user details will be deleted permanently as soon as the research was completed.

The survey responses helped to identify the weak points, where possible improvements are needed most, and strong points as well.

3.3 Surveys and Questionnaires

The user survey was composed of eight sections. Each section was specifically aimed to extract targeted information to support further app development.

1. **Personal Information:** This section used to capture the participant's demographic data, such as age group, gender, continent of residence, professional background, and prior experience in environmental activities. This information helps to understand the user profiles of the participants.
2. **App Usage and Experience:** In this section participants were able to rate their experience on app navigation, interface design, content relevance, and gamification features. Also, they were asked to identify the favorite features of the application and areas that need to improve. This section was aimed at identifying the usability, user satisfaction, and the app's motivational factors.
3. **Social Media Integration:** In this section aimed to find how users value the social media integration within the application. Also captured participants' opinions on sharing achievements on social media and promoting cleanup events through social media.
4. **Improvements and Suggestions:** This section offered open-ended multiple-choice selections, mainly targeted to capture usability improvements, participants' suggestions regarding missing features, improvements on existing features, and ultimately whether they would use the app post-launch and recommend it for others.

5. User Experience on Environmental Conservation: Captured the participant history of participating in cleanup events and experience if they have used similar environmental-related apps.
6. Environmental App Experience: If participants have used similar apps, this section designed to capture feedback on their experience and perceptions.
7. Other Environmental Apps: Participants who have used other environmental apps are able to provide feedback on the comparison with the Green Savers app related to strengths, weaknesses, and feature gaps.
8. Final Thought: The closing section invited to provide any suggestions or feedback to improve the overall app experience and engagement.

This well-structured survey ensured that both quantitative data (ratings and selection) and qualitative data (written suggestions and experiences) were gathered for the optimal data collection. With these inputs further refinements and feature enhancements made the Green Savers app more closely align with the target audience.

The complete list of survey questions used in this study is provided in Appendix 1.

3.4 Usability Testing of the Prototype

Using the Figma tool, a clickable prototype was developed for evaluating the usability of the Green Savers mobile application. The primary objective of the prototype is to mimic the core functionalities such as user onboarding, event creation, leaderboard access, article view, and user profile interaction. The usability testing was carried out to assess the intuitiveness, design clarity, and user satisfaction of the application's core flow.

Usability testing was conducted remotely by providing a survey link via social apps to the participants. Then the cloud-based Figma prototype link was embedded in the survey into the introduction of the survey. Then participants were instructed to explore the app prototype prior to answering the structured online survey. Since this was a Figma prototype, the interactivity is limited to pre-designed screen transitions and user flows. Therefore, this was not equipped with any backend functionalities.

With the prototype participants were able to perform tasks such as:

- Navigating through the welcome, login, and account creation pages.
- Exploring the home screen, viewing and creating events.
- Viewing statistics, leaderboard, and milestone progress.
- Trying out map-based location search and calendar scheduling.
- Explore global news articles and environmental conservation knowledge awareness articles.
- Engaging with event-specific chat features.

After familiarizing themselves with the prototype, participants responded to the survey questions such as navigation easiness, interface design, gamification elements, and feature usefulness.

Overall, the responses provided are mixed but mostly lean towards a positive outlook. Most of the participants found out that navigation is “somewhat easy” or “very easy”. Meanwhile, some of the participants expressed that navigating through some of the pages needs to be more streamlined. Interface feedback also were mostly leaned toward the positive side. Some of the participants highlighted the color scheme, button placements, and icon usage need more improvements.

Even though this testing did not involve live user tracking or screen recording due to the remote access, collected data was sufficient enough to understand the overall app’s pain points and areas need for improvement. Based on the survey results, several UI improvements were planned, including more icon usage for menus, clear labelling for navigation elements, improved spacing and alignments, usage of proper tab view instead of using buttons, and enhancing overall visual clarity within the application.

Overall, even with the pre-designed limited prototype functionalities, the usability testing provided valuable insights for reshaping the app for a more intuitive and engaging experience.

3.5 Data Analysis and Key Findings

3.5.1 Participant Overview

A total of 39 individuals participated in the survey. Most of the participants were from Asia and age belonged to the group of 25-44. The majority of participants were males, and most of the participants are professionals in the Information and Communication Technology (ICT) sector. Participants' engagement in environmental-related activities varies between active participation and occasional or no involvement at all.

3.5.2 Quantitative Data Analysis

- Navigation Experience: More than 60% of the participants (Figure 15) found that navigation between the interfaces was "somewhat easy" or "very easy". This indicated that the users are generally pleased with moving across screens without confusion.

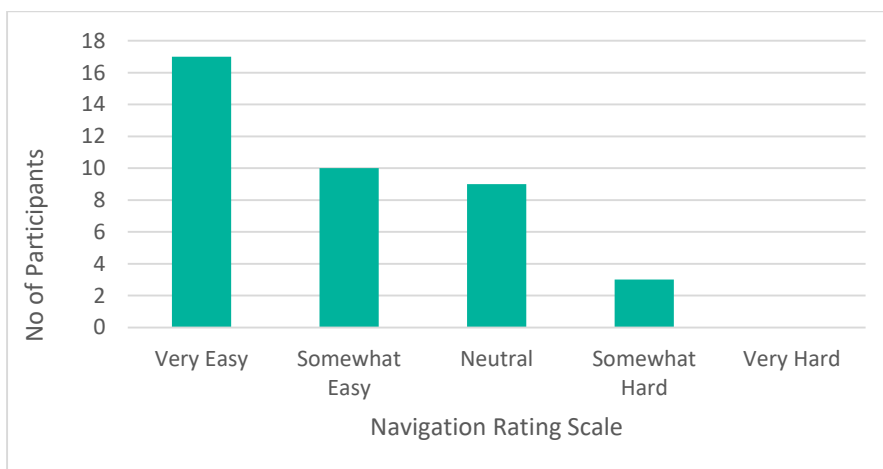


Figure 15. Distribution of Interface Navigation Ratings

- UI design feedback: Feedback for the user interface was mixed, the majority found it "somewhat appealing" or "very appealing", while few rated it as very unappealing or neutral (Figure 16). But the majority of the feedback was leaning toward positive. Mostly attributed to the clean layout and color selection, while suggesting a focus on spacing and icon placement.

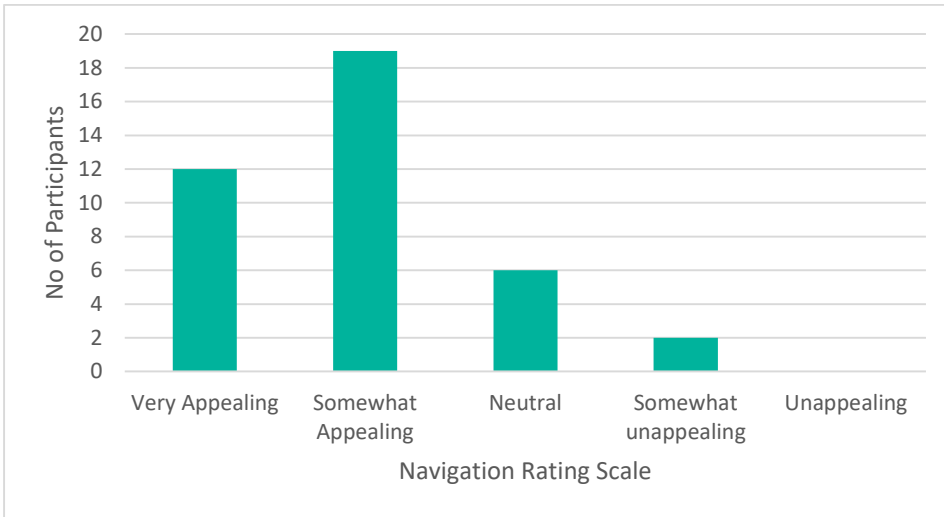


Figure 16. Distribution of User Interface Design Ratings

- Feature Preference: From all the participants, almost 75% voted ease of use as the most liked feature in the app. Additionally, they choose map integration, intuitive interfaces, eco-friendly products and knowledge center, and the app’s core purpose (community-led cleanup) as their most liked features (Figure 17).

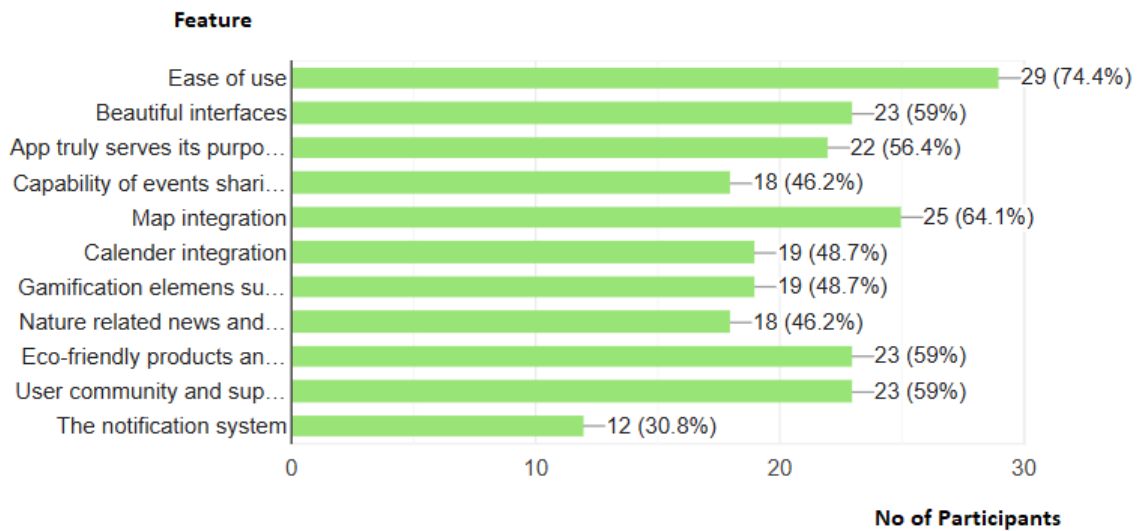


Figure 17. Rating of App Features

- **Motivational Elements:** Almost 80% of the participants voted that milestones, experience points, and badges will encourage and motivate users to engage frequently with the app's core purposes.
- **Social Media Integration:** More than 68% of participants voted social media integration and sharing as a positive feature in the app, while 23% found it neutral, and 8% found it as not very important (Figure 18).

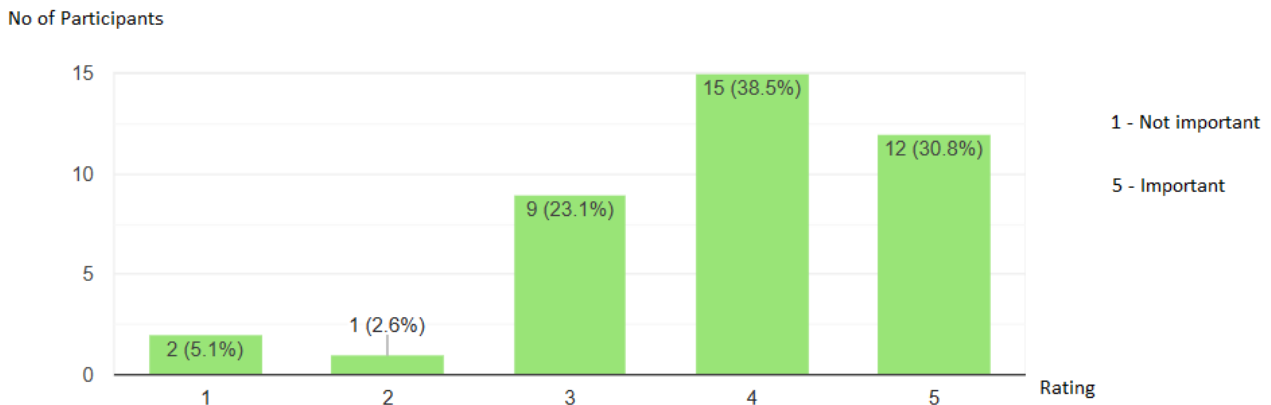


Figure 18. Ratings of Social Media Integration and Sharing

- **App Satisfaction:** On a scale from 1 to 5, 85% of the participants rated their satisfaction as 4 or 5, and only 15% of the participants found it as neutral (Figure 18). There were 0 votes rated as the app is unsatisfying. This gave a strong meaning that the app already has strong potential with minor improvements.

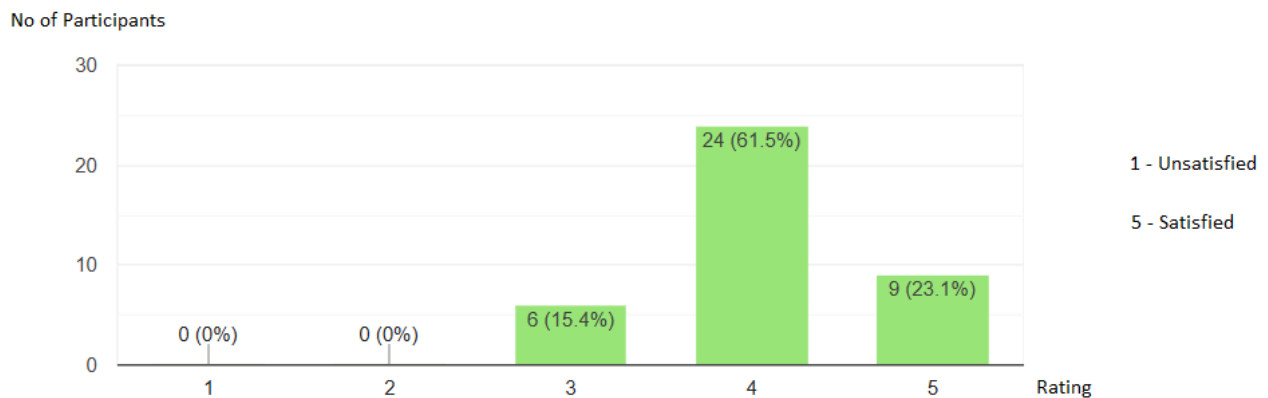


Figure 19. Overall App Satisfaction

3.5.3 Qualitative Data Analysis

The survey also included open-ended questions to collect user suggestions, opinions, and expectations. These qualitative responses provided valuable insights into the actual user requirements, giving clues about what and how to enhance the user experience and engagement in the app. Also, new considerations for the future development of the application. Some of the key points filtered from the analysis are,

- **Community Interaction and Communication:**
Many users suggested their desire for deeper community engagement within the app. While the prototype was already equipped with an event-specific chat feature, participants suggested a global chat for broader environmental discussions and cross-region collaboration.
- **Personalization Features:**
Participants also highlighted the importance of personalization of themes as they prefer dark mode or apply color themes. Also, proposed multiple language selections for helping non-English speakers and local communities. Some suggested that a customizable font size would help for users who prefer larger fonts.
- **Support for Donations and Transparency:**
Several participants suggested including a donation gateway or funding system for supporting such events and non-profit environmental organizations to contribute to verified environmental causes or events. Also suggested that adding an impact report, such as event statistics reports.
- **Guided Workflows and Improved Onboarding:**
Some responses outlined the need for a few guiding screens or tutorials for fresh starters, such as creating a new event and other navigation through the application. Also suggested the need for tooltips for confusing sections.
- **UI improvements:**
Some of the participants suggested that showing the number of participants in the upcoming events section would be helpful to understand how many volunteers already have or if event is already full. Also suggested the use of common icons for menus widely used in mobile applications.
- **App Simplicity and Focus:**

A few respondents highlighted the importance of keeping the app simple and lightweight. Instead of sharing global news data, which is somewhat getting less interest, sharing own app events-related data in the news section could be more motivating for the users in the community.

4 Mobile Application Development Based on Research Findings

4.1 Finalizing Requirements Based on Research

Following the completion of user surveys and usability testing of the app prototype, a set of clear requirements was finalized for the development of the Green Savers application. These summarized requirements were informed by survey participants' preferences, feedback and identified usability gaps. To meet both core objectives of the application and user expectations, the development ensured that the final product will be functional and impactful.

Including the already placed features and functions of the application, these were summarized,

- **Event Creation and Participation:** Most of the users were greatly appreciated the core idea of the application, which is event creation and participation. Some of the users requested a more streamlined and structured event creation form and include fields such as event title, number of volunteers needed, number of volunteers already volunteered, date, location, and event type.
- **In-App Communication:** Most of the participants requested and appreciated the chat feature of the app for event-specific and usual chat features between the community members. Therefore, event-specific chat enabled for a better coordination and communication among the volunteers. A future enhancement is included for "Green Community Space", where users can share ideas, knowledge, and environmental tips, and also event results.
- **Gamification Elements:** Since the survey participant found that gamification elements are motivating and engaging, XP points, milestones, and badges were included to reward users for creating events, completing events, participating in events, hours spent in events, amount of litter collected in events, and inviting more users to the community. Additionally, a global and local leaderboard was added to appreciate and create a sense of competition within the recognized community.
- **Personalization Options:** Many users highlighted that requirement of multiple languages, currently the app is designed with the English Language, and integrating more languages is added for future plans. Options for switching between themes also added for future plans.

- **User Profile and Statistics:** To enhance user's own satisfaction and self-appreciation, profile screen was enhanced with user statistics to show total events created, participated, completed, hours spent, litter collected, and green friends. Future features include as generating and sharing user stats and personal impact reports.
- **Data Privacy and Transparency:** The app is designed to follow the GDPR principles and to protect users' sensitive data. Clear consent messages were prompted prior to accessing any other important data which is required to show and to generate.

All finalized requirements are validated based on user feedback from the survey. This ensured that the app is not only technologically simple and impactful but also well-aligned with real-world user preferences and expectations. With these finalizations the project remains focused on delivering a balance of usability, proper user engagement, and most importantly, environmental impact.

4.2 System Architecture and Design

Since the project follows an iterative approach, few changes were made to the existing system flow based on the feedback received during the user survey. While the overall app structure remains the same with the original design principles, a few additional functions are added to the app for enhanced usability and feature control. Mainly the "My Events" section was added to allow users to view events created by themselves. Following the same screens, users are now able to view, delete, and complete an event by entering the final cleanup data. However, the core navigation and modular screen structure flow remained unchanged due to the proper planning and designing in the initial phase. Figure 20 illustrates the new updated version of the Green Savers app design flow.

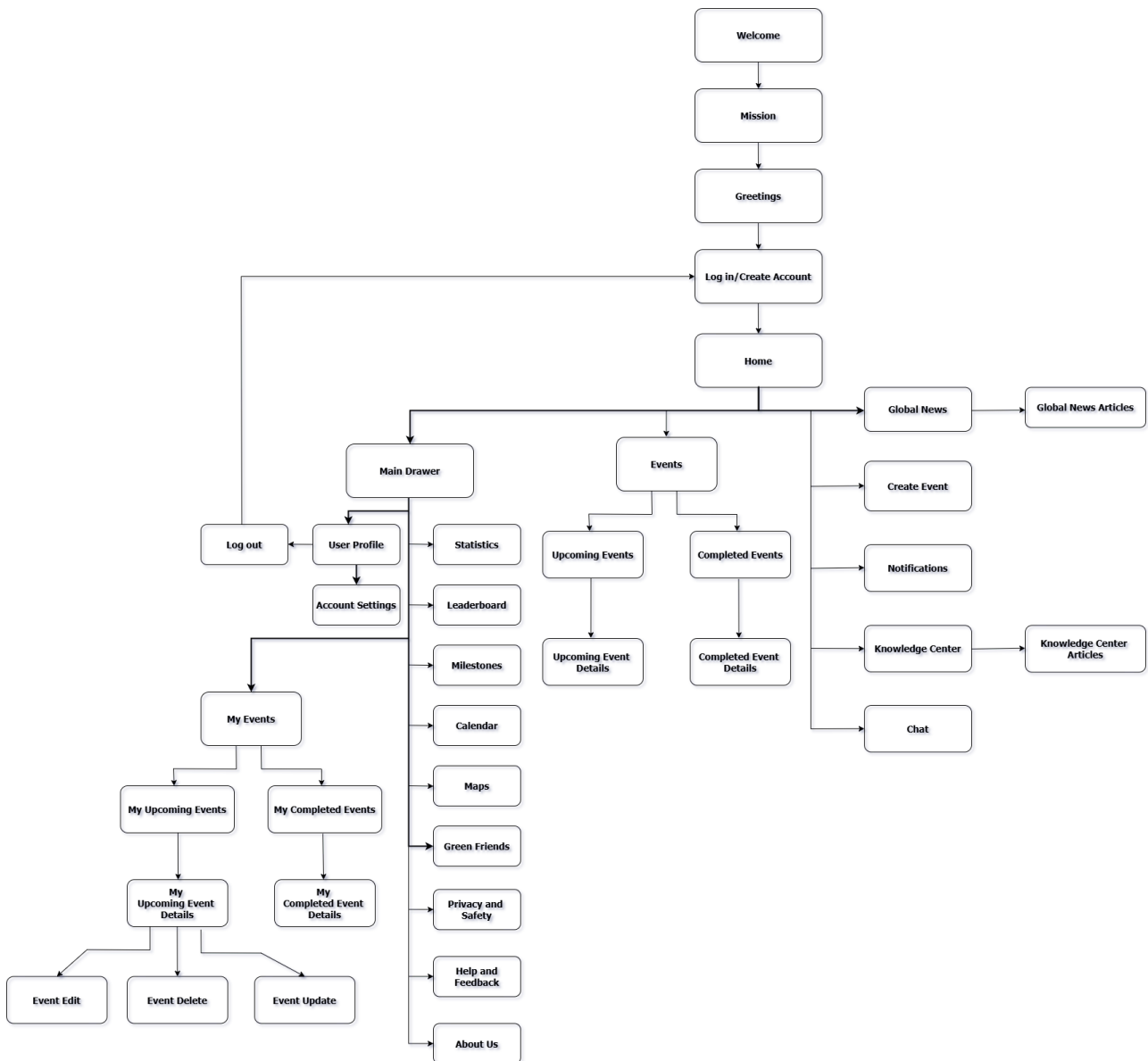


Figure 20. Updated Design Flow of Green Savers App

To develop the Green Savers mobile application, client-server architecture was used. Also, this model is well suited for modern cross-platform applications due to its scalability and separation concerns (Rittinghouse & Ransome, 2017). This model supports effective and efficient communication between the front-end and the back-end of the application with supportive features such as dynamic data operations, real-time updates, and scalable community engagement features which are essential for environmental conservation activities.

The development frond-end of the application uses Flutter framework, enabling a single codebase for targeted multi-platforms of both Android and iOS. Flutter offers high-performance rendering,

widget customization, and reactive UI patterns, giving full customizing ability to developers for building visually engaging and interactive user interfaces. State management was handled using Riverpod, a robust Flutter package designed for robust and scalable solutions that promotes modularity and testability.

For the back-end, app integrated with Google's Firebase with its core features, such as

- Firebase Realtime Database for low-latency read/write operations.
- Firebase Authentication for secure login and user identity management (future planned).
- Firebase Storage for storing multimedia files related to events.

4.2.1 Application Structure

The application follows a layered architecture (Figure 21) to support clean code maintenance and for future scalability. The primary layers are included,

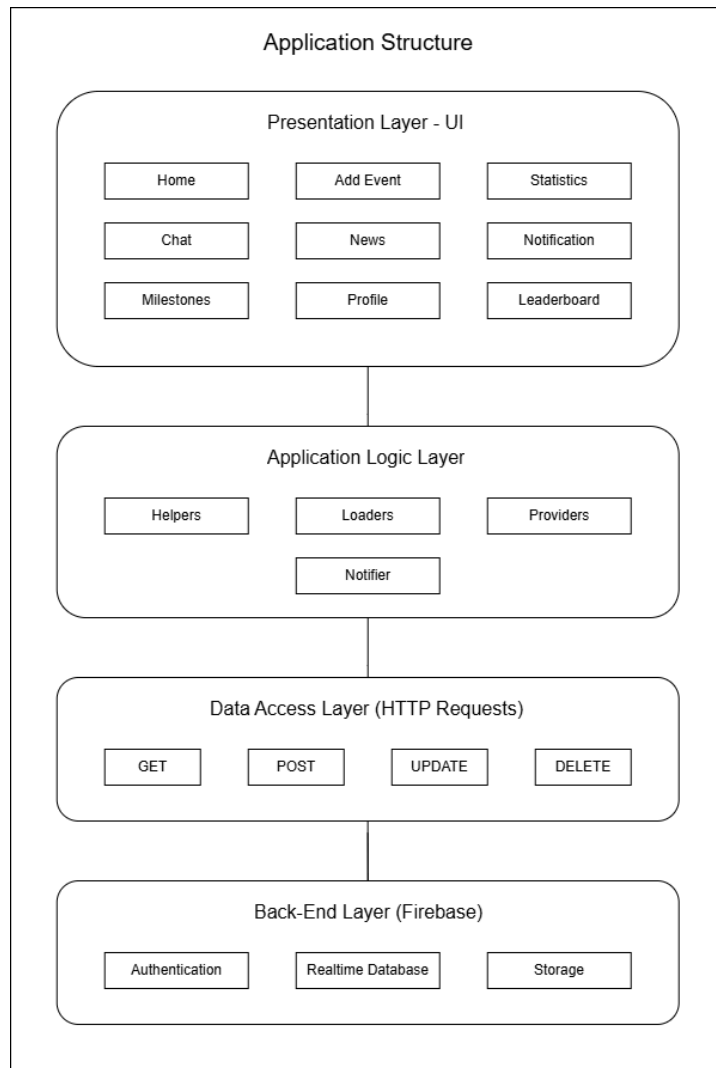


Figure 21. Application Structure

- **Presentation Layer (UI):** This layer was built using Flutter widgets. The layer handles all visual aspects, such as the home screen, adding events, chat, news articles, statistics, and profile. The UI is reactive and uses Riverpod for state management.
- **Application Logic Layer:** This layer contains state notifiers, helpers, and providers. These are handling user inputs, notifications, routing, UI state updates, and managing app flows such as event volunteering and various calculations.
- **Data Access Layer:** This layer communicates with a real-time database, authentication, and storage in Firebase. And the layer is responsible for HTTP requests such as GET, POST, UPDATE, and DELETE and uses the HTTP package. This layer also handles the shared_preferences package for session handling and caches user data locally on the device used.

- **Back-End Layer:** Primarily use Firebase for the backend and core features such as Realtime Database, Firebase Storage, and Firebase Authentication. A Realtime Database used for storing data related to events, users, chats, and notifications.

4.2.2 Data Models and Database Design

Firestore Realtime Database is used as the primary backend service for storing data and syncing data between the devices. The Firestore Realtime Database uses a non-relational and hierarchical schema for storing data. Therefore, this method supports quick data retrieval from the database to devices.

There are five primary nodes in the database structure,

1. **users/:** This key node stores user profile details and the user's statistics. Data included in the primary key node are display name, mobile number, email, country, units, user category, number of green friends and language. There is a dedicated child node called "user_statistics" for storing users' statistics data, and it stores data keys for events participated in, created, completed, milestones, badges (future plan), hours spent in cleanup events, and the amount of weight that litter collected.
2. **events/:** This primary node stores data related to each environmental activity under a unique event ID. Key attributes in this node are title, date, time, event type, creator ID, location (latitude and longitude), number of volunteers needed and joined. Post-event data attributes are, total litter collected, number of volunteers who participated, event duration in hours, and XP points. Also, it stores all the volunteer's user IDs under the child node "volunteeredUserIds".
3. **global_event_statistics/:** In this primary node, maintains cumulative global statistics used to display application impact on a global scale. Key attributes are total cleanup events completed, total litter collected, total volunteer hours, and total volunteers who participated in events.
4. **chats/:** This node contains event-dedicated chats that enable real-time communication between event participants. Each chat node has a unique chat ID

and is uniquely identified by the event ID. The rest of the data are the message lists of the participants. Attributes are sender ID, message content, and timestamps.

- 5. notifications/:** Used to notify users about newly created events or updates. This node is structured under each user ID and contains the event ID, title, message, and timestamp.

The hierarchical structure of the database is illustrated in the following figure 22. It displays the five root nodes mentioned above, and sample child nodes with sample data, displaying that how environmental event data, chat messages, and user information are organized.



Figure 22. Hierarchical Structure of the Firebase Realtime Database Schema.

4.2.3 User Authentication and Data Security

Currently, In the Green Savers mobile application uses a custom, manual authentication for user login. Users can log into the app by using either their email address or mobile number along with a password. These encrypted credentials are stored in the Firebase Realtime Database. Currently this method provides a functional but lightweight method for user access control. The Green Savers app will migrate to Google’s Firebase Authentication in the future to facilitate one of the industry-leading authentication method for app users. This will enhance the app’s scalability, better session management, and integration with other Firebase services (Firebase, n.d.).

Even though the currently app uses a lightweight authentication system, it still provides a strong authentication mechanism. To ensure the users’ confidentiality, passwords are not stored or transmitted into the DB in plain text. Instead, passwords are hashed using the SHA-256 algorithm using the “Crypto” Flutter package before transmit to the DB over the internet. This mechanism runs on the device locally as soon as the authentication process is initiated. This provides a basic but effective security mechanism against any unauthorized access. The following Dart snippet (see Figure 23) shows the password hash process,

```
String _hashPassword(String password) {  
  final bytes = utf8.encode(password);  
  final digest = sha256.convert(bytes);  
  return digest.toString();  
}
```

Figure 23. Password Hash Process

With this method, even if the database is exposed, it is not readable or reversible. Although this process is being done manually, it aligns with standard password protection practices for non-OAuth-based systems (Vaideeswaran, 2024).

In the app, session control is handled with using the `shared_preferences` package. It stores the user ID locally in the device at the time the user logs into the app. This enables the persistent navigation and app usage without requiring the user to log in repeatedly.

In the future, the Green Savers app will use Firebase Authentication to provide stronger identity management, built-in session handling, and advanced features such as password reset, social login integration, email verification, and, most importantly, multi-factor authentication to align with best industry practices.

4.3 Frontend and UI Implementation

To develop the front-end of the application, the Flutter Framework with the Dart programming language was selected. Flutter supports cross-platform development and is designed for building natively compiled applications for mobile, web, and desktop from a single codebase (Google, n.d.). Flutter is one of the best toolkits due to its vast widget library, fast rendering engine, and modern design philosophy. Also, using Flutter, developers are able to design responsive and visually stunning mobile applications.

Over the past years, Flutter has gained significant popularity among the cross-platform mobile application developers. Below, Figure 24 shows the popularity of Flutter compared to other cross-platform mobile frameworks in the recent years globally. Some of the key points for that popularity among are, hot-reload capability and modular widget system. Also, it has become one of the most actively maintained frameworks for mobile development due to a large active open-source community (Vailshery, 2025).

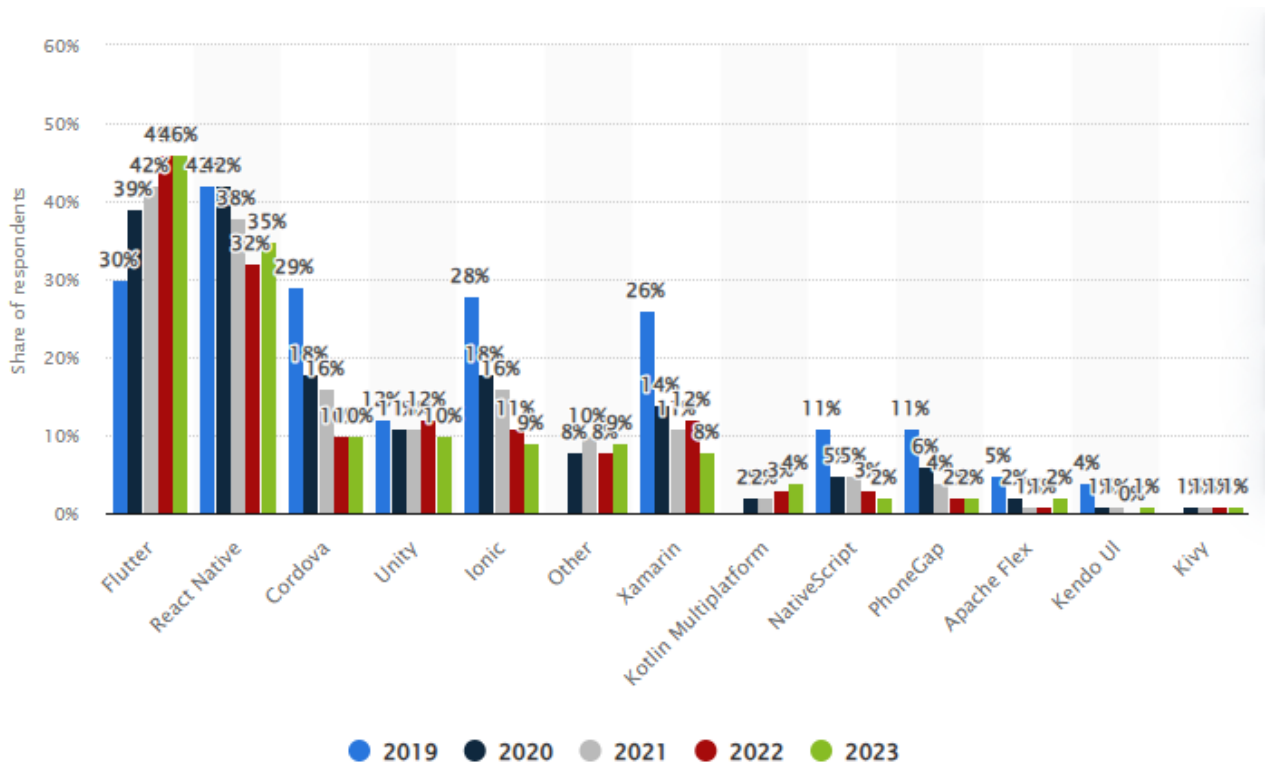


Figure 24. Cross-platform mobile frameworks used by developers globally, 2019–2023.

(From Vailshery, 2025, Statista)

Apart from the in-built Flutter packages, a variety of packages were installed to implement various features in the Green Savers app. When selecting external packages, carefully select based on their credibility, popularity within the professional Flutter community, and long-term maintenance status. Also, the author always preferred packages developed or maintained by the official Dart or Flutter teams or those widely adopted and actively maintained by experienced professional developers. This approach ensures the improved reliability, community support, and forward capability, making the app future-proof. Below, Table 2 shows the external packages used for the development of the application.

Table 2. External Packages Used in the Green Savers App.

Package Name	Purpose
cupertino_icons	Provides iOS style icons used in the UI
google_fonts	Allows the use of custom Google Fonts in the UI
flutter_launcher_icons	Generates app launcher icons for Android and iOS
url_launcher	Launches URLs in the browser or other apps
google_maps_flutter	Displays Google Maps inside the Flutter app
geolocator	Retrieves the current location of the device
location	Gets location updates and permissions
flutter_polyline_points	Draws polylines (paths) on maps
flutter_google_maps_webservices	Interacts with Google Places and Geocoding APIs
table_calendar	Provides a customizable calendar widget
http	Performs HTTP requests (GET, POST, PATCH)
intl	Formats dates, numbers, and currencies
flutter_html	Renders HTML content in widgets
webview_flutter	Embeds web content using a WebView
geocoding	Converts coordinates into readable addresses
intl_phone_field	Validates and formats international phone numbers
crypto	Performs password hashing using SHA256 and other algorithms
shared_preferences	Stores key-value pairs locally for session management
flutter_riverpod	Manages app state efficiently
image_picker	Picks images from the gallery or camera
firebase_storage	Stores and retrieves media files in Firebase
firebase_core	Initializes and configures Firebase
share_plus	Shares content like text and images with other apps
firebase_database	Connects to and interacts with Firebase Realtime Database
permission_handler	Manages runtime permissions for Android/iOS
flutter_contacts	Accesses and manages contacts for friend invitations

4.3.1 Flutter Components

In Flutter, components are known as ‘widgets’, and these are the fundamental building blocks of user interfaces. Every item a user sees in the interface is built with a specific widget or using a layered set of widgets (Chavda, 2024). To understand the concept of Flutter widgets, refer to Figure 25 shown below. Flutter’s own core layout widgets like ‘Column’, ‘Row’, ‘ListView’, and ‘Scaffold’ extensively used for building the foundation of most of the screens. To manage local and global states through Riverpod, ‘ConsumerStatefulWidget’ is used in many screens.

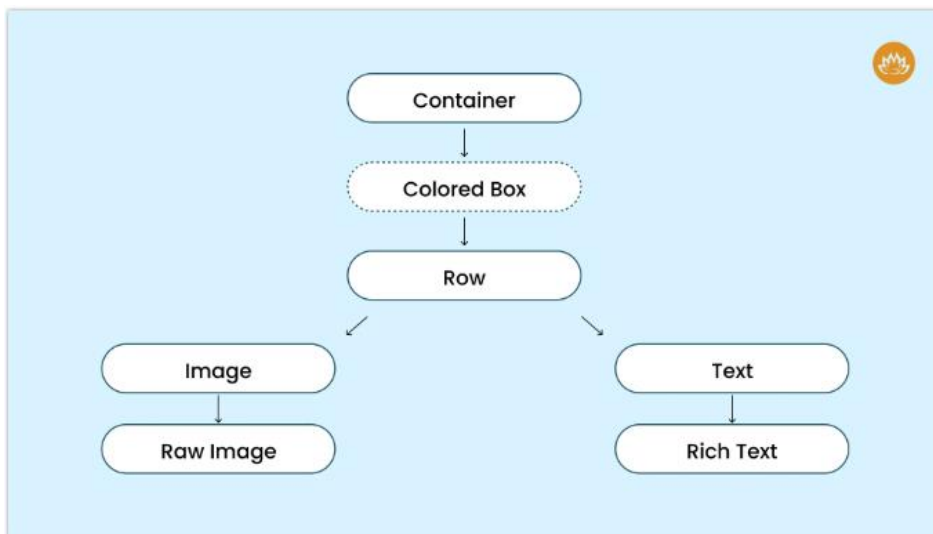


Figure 25. Concept of Flutter Widgets. (From Chavda, 2024, www.whitelotuscorporation.com)

4.3.2 Custom UI Elements for User Engagement

Several custom widgets have been built in the Green Savers app to maintain the application’s visual consistency, user motivation, and interaction feedback. In the gamification section, a dynamic XP progress indicator and a collection of milestone badge components were developed to show users meaningful environmental contributions.

Reusable custom widgets such as ‘CustomButton’ and ‘CustomAppBar’ were built to maintain a consistent visual theme across the application. These widgets standardize the look and feel of action buttons and screen headers with the facility of customization for color, text, and shape.

Also, there are several reusable card widgets created to control the consistency and modularity within the application. For example, pinned 'EventInfoCard' is used to display event summary details at the top of the screen in the chat screen. The upcoming and completed events screens utilize 'UpcomingEventsCard' and 'CompletedEventCard' respectively. Also, created full detail cards to display full event details as well in both completed and upcoming sections.

Additionally, animations and feedback elements such as success dialogs, toast messages, and snackbar alerts were included in the app to provide intuitive responses to user actions. These custom widgets not only provide usability but also improve the users' engagement and satisfaction, encouraging repeated use.

4.4 Backend and Database Integration

The app uses cloud-based Firebase Realtime Database for data storage, and the database is structured using a hierarchical JSON format. Currently, the database is having five main key nodes, 'users', 'events', 'chats', 'notifications', and 'global_event_statistics'.

The application interacts with Firebase via direct REST API using the HTTP package. The app performs CRUD (create, read, update and delete) operations using HTTP methods such as POST, GET, PATCH, and DELETE directly in the Firebase Realtime Database. This enables customizable operations over data management compared to Flutter Firebase SDK.

For example, whenever a user completes an event, the app sends a PATCH request to update relevant nodes with values such as collected litter weight, event duration, number of participants, and update user statistics at the same time. All of these requests are structured using JSON and then sent to the Firebase endpoints. Database access controls are defined using Realtime Database Security rules.

For a code example, the following code snippets demonstrate how a new event is created in the Firebase Realtime Database using the HTTP POST method, which is a create operation in the CRUD model.

When a user logs into the system, the user ID and country (filtered from their mobile number) are stored in locally using the SharedPreferences package. Same SharedPreferences package used to extract user ID and country whenever needed (Figure 26). This information is extremely useful for filtering and distributing events to users within the same country or region.

```
final prefs = await SharedPreferences.getInstance();
final userId = prefs.getString('userId') ?? 'unknown_user';
final userCountry = prefs.getString('userCountry') ?? 'Unknown';
```

Figure 26. Extract UserID and Country From SharedPreferences.

Then a POST request is sent to the 'events' node in Firebase to create a new event record along with other essential event details (Figure 27), specially including the event creator's country.

```
final url = Uri.https(
  'green-savers-266a6-default-rtdb.europe-west1.firebaseio.com',
  'events.json');

final response = await http.post(
  url,
  headers: {
    'Content-Type': 'application/json',
  },
  body: json.encode(
    {
      'title': _titleController.text,
      'eventType': _selectedEventType ?? 'Unknown Event Type',
      'date': _selectedDate?.toIso8601String() ??
        DateTime.now().toIso8601String(),
      'fromTime': formatTime(_fromTime ?? TimeOfDay.now()),
      'toTime': formatTime(_toTime ?? TimeOfDay.now()),
      'location': {
        'latitude': _selectedLocation?.latitude ?? 0.0,
        'longitude': _selectedLocation?.longitude ?? 0.0,
      },
      'volunteersNeeded':
        int.tryParse(_volunteersNeededController.text) ?? 0,
      'createdByUser': userId,
      'country': userCountry,
      'numberOfVolunteeredUsers': 0,
      'eventStatus': 0,
    },
  ),
);
```

Figure 27. POST Request Sent to 'Events' Node.

Then later, this country value is used to fetch only those events that match the logged-in user's country. This makes sure that the users only view the events within the country.

4.5 Google Maps and Location Services Implementation

The application uses several maps-related packages such as 'google_maps_flutter', 'geocoding', 'geolocator', and 'flutter_google_maps_webservices' to provide the most accurate and informative data to users. Users can pick pinpointed locations using precise latitude and longitude values to ensure the highest accuracy of the place where the event will take place. Once a user selects the location on the map, the application immediately executes the reverse geocoding service to get and display the nearest recognizable place name. Permission for location access is managed using the 'permission_handler' and 'location' packages.

This method greatly reduces the risks, such as user errors and confusion, that may arise from having similar place names (e.g., rivers with the same name or even similar city or village names across regions). These executions are extremely vital, especially in applications that heavily rely on location details. Also, this will improve both the clarity of event details and the accuracy of geospatial data stored in the database.

The following code snippet (Figure 28) illustrates the reverse geocoding process used in the application:

```
Future<String> _getPlaceNameFromCoordinates(LatLng position) async {  
  final url =  
    | 'https://maps.googleapis.com/maps/api/geocode/json?latlng=${position.Latitude},${position.Longitude}&key=$apiKey';  
  |  
  final response = await http.get(Uri.parse(url));  
  final data = json.decode(response.body);  
  
  if (data['status'] == 'OK') {  
    final result = data['results'][0];  
    return result['formatted_address'] ?? "Unknown Location";  
  } else {  
    return "Unknown Location";  
  }  
}
```

Figure 28. Reverse Geocoding Process.

This feature is used on various screens in the application. Some of the screens are, event chat summaries, upcoming events, upcoming events full details, completed events, completed events full details, and my events sections. In the Firebase Realtime Database only stores latitude and longitude values for each event in order to provide maximum location accuracy.

4.6 User Testing and Iterative Improvements

During the development of the Green Savers mobile application, extensive user testing sessions were conducted. These testings were conducted in both Android emulators and physical devices to validate the app's core functionalities and performance in different environments. Testing was carried out parallel with every implementation of widgets, screens, and major features. This process fulfilled the iterative development approach where feedback was gathered from each cycle and immediately applied fixes and improvements if required.

In this process,

- **Emulator-Based Testing:** Used primarily in the initial development stages. Mainly for UI layouts, navigation logics, and state management.
- **Physical Device Testing:** Upon completion of core features (event creation, completion, volunteer toggle, chat integration, and Google Maps features) and other implementations, physical devices were used to test the real-world situations such as GPS behaviour, Google Maps features, gesture handling, and application performance. The application's performance evaluation was carried out on multiple physical devices with high-end and low-end hardware specifications to ensure that the app runs on any device.

Although the app has not yet deployed on either Android's Play Store or Apple's App Store, the core features are fully developed and successfully tested. These includes,

- User profile management and statistics tracking,
- Event life cycle (create, edit, delete, and complete),
- Volunteer toggle and XP system,

- Google Maps location selection and reverse geocoding,
- Fully functional event-dedicated chat feature,
- Fully functional notification system.
- Leaderboard,
- Overall application statistics,
- Milestone logic,
- Fully functional 'Green Friends' section (View contacts and invite system),
- Fully functional knowledge and action center.

However, there are still some of the features yet to be implemented prior to the deployment, mainly the fraud prevention system and setting up deployment configurations.

5 Evaluation and Discussion

5.1 Comparison of Prototype and Developed Application

This section presents the comparative analysis between the initial Figma prototype and the final version of the Green Savers mobile application. Prototype features were designed solely based on the author's experience in environmental conservation activities, and UI/UX was designed according to the best practices in the industry. Then the app development phase involved refinements from user survey feedback, practical implementation considerations, and aesthetic improvements.

The screenshots presented in this section were captured directly from a physical Android device (Google Pixel 9 Pro XL). In some of the figures, prototype images alongside corresponding developed app screens highlight key changes in layout, color choices, iconography, spacing, and added functionalities.

Some of the certain sections of the application, such as the global news, knowledge and action center, article viewer, maps, calendar, and notifications screens, have remained the same or with only minor visual or functional changes, as their initial layout aligned with user expectations.

Note on Figure Layout: In the following figure comparisons, if prototype version images are available, then they are consistently placed on the left, and the corresponding screenshots from the actual developed application are placed on the right. For newly added features or screens that were not part of the original prototype, only the developed app images are shown.

Figure 29 illustrates the updated login screen. Changed the input fields to login credentials to follow industry standards instead of highlighting account creation. Also, placed the double-entry fields to improve input accuracy to eliminate user errors.

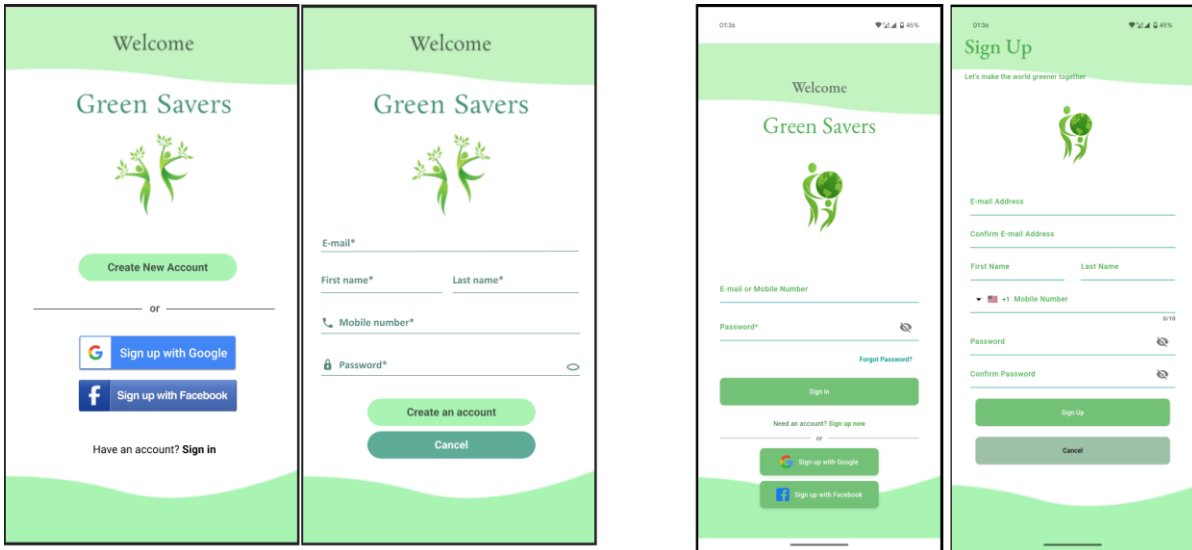


Figure 29. Login and Signup Screens Comparison.

When users sign up for the app for the first time, added a warm welcome screen to show appreciation and to create a positive first impression (Figure 30).

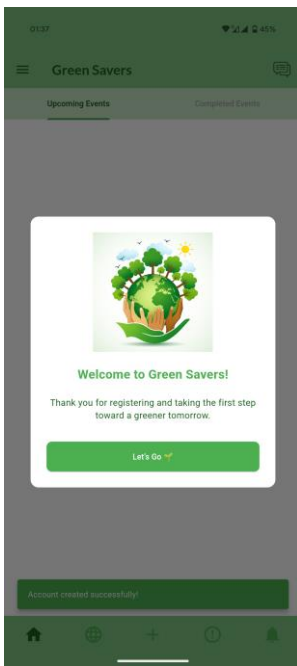


Figure 30. Welcome Screen.

The following Figure 31 illustrates the revamped tab view instead of using buttons for viewing upcoming events and completed events on the home screen. Also, improved the images to have a

minimalistic yet modern look. Additionally, the number of volunteered users added to the event card gives an idea to the user if the event has already reached its required capacity. In the main menu, icons are added as an industry standard to give a quick visual cue for each section's purpose. Text labels were also centered and spaced properly within dividers to enhance clarity and overall layout balance.

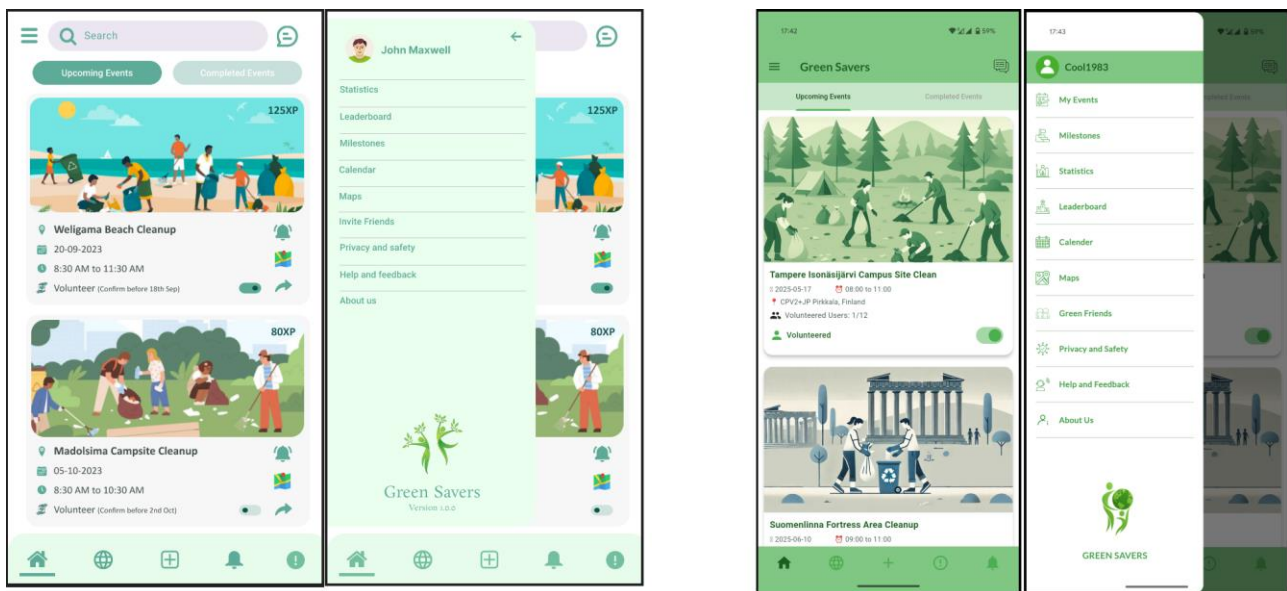


Figure 31. Home Screen and Main Menu Comparison.

In the create events screen (Figure 32), few but very important fields are added, such as the number of volunteers needed and the event location type for creating events with more information. The number of credits option has been removed since it is calculated (when submitting completed event details) based on event duration in hours and the weight of litter collected during the event. Also, added validation for all the fields and shows the event duration (under the time selection row) as a hint for the event creator how long the event will take place. Also, location selection now takes place on a separate screen, and once the user selects and confirms the location, they are guided back to the create event screen automatically.

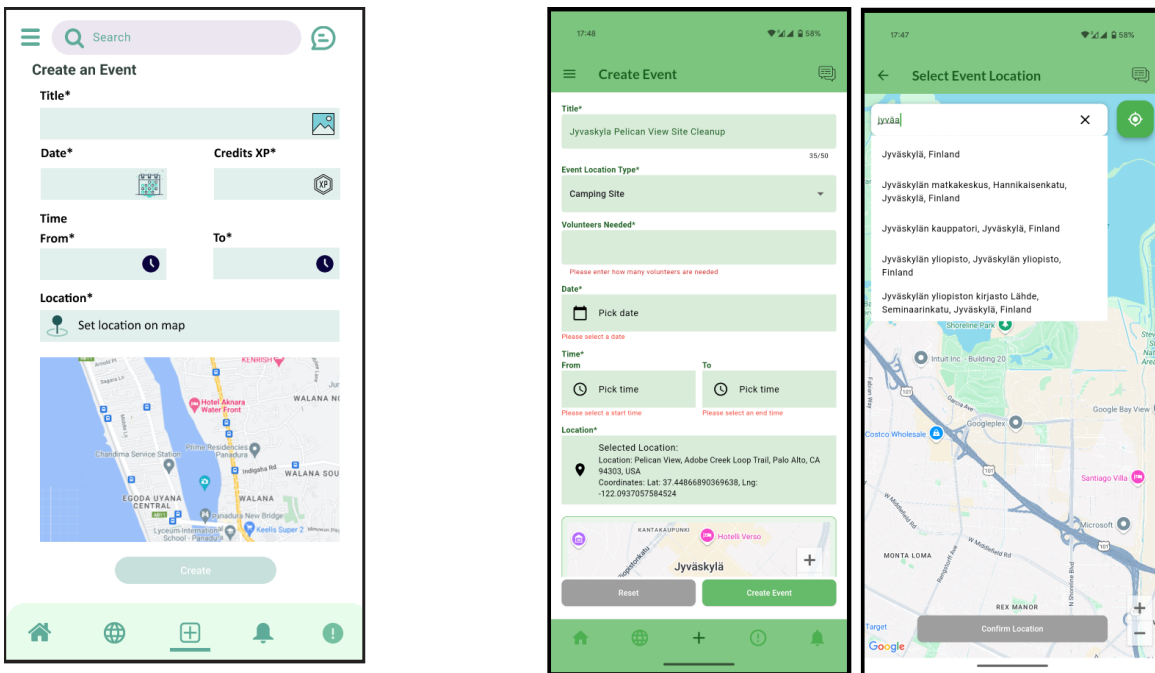


Figure 32. Create Event Screens Comparison.

Figure 33 illustrates the statistics and leaderboard screens. New screens are more simplified and have added an appropriate image to match the title. Additionally, in the leaderboard, the logged-in user's name is highlighted with a background color to make it easily distinguishable.

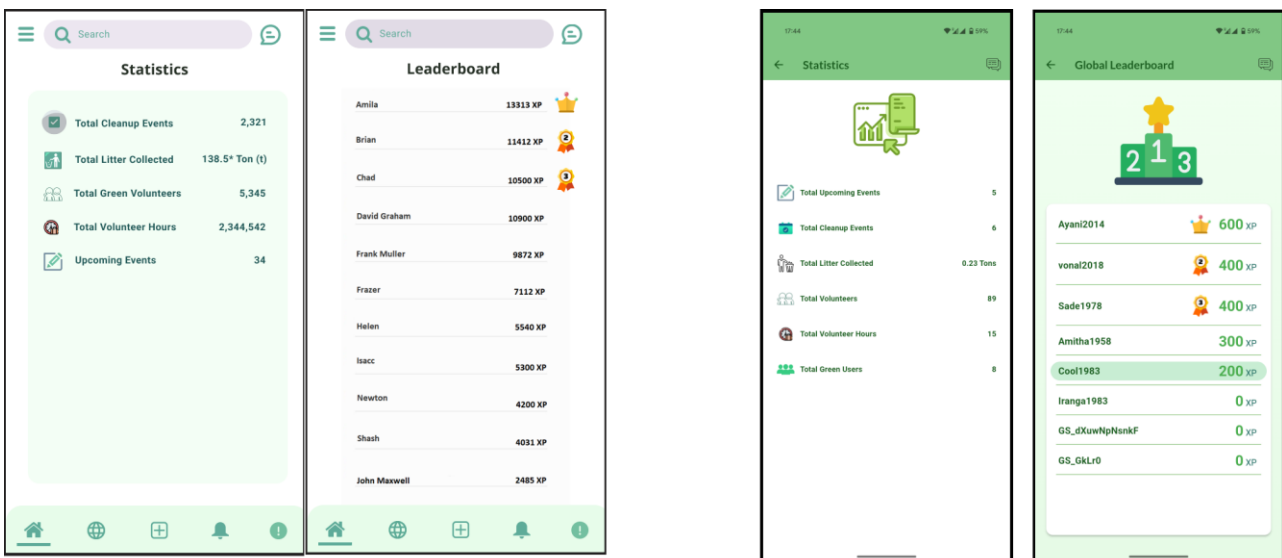


Figure 33. Statistics and Leaderboard Comparison.

In the following, Figure 34 illustrates the user profile screen and account settings screen along with a password change screen. Newly added fields are litter collected in user profile statistics, display name, and mobile number in the account settings screen.

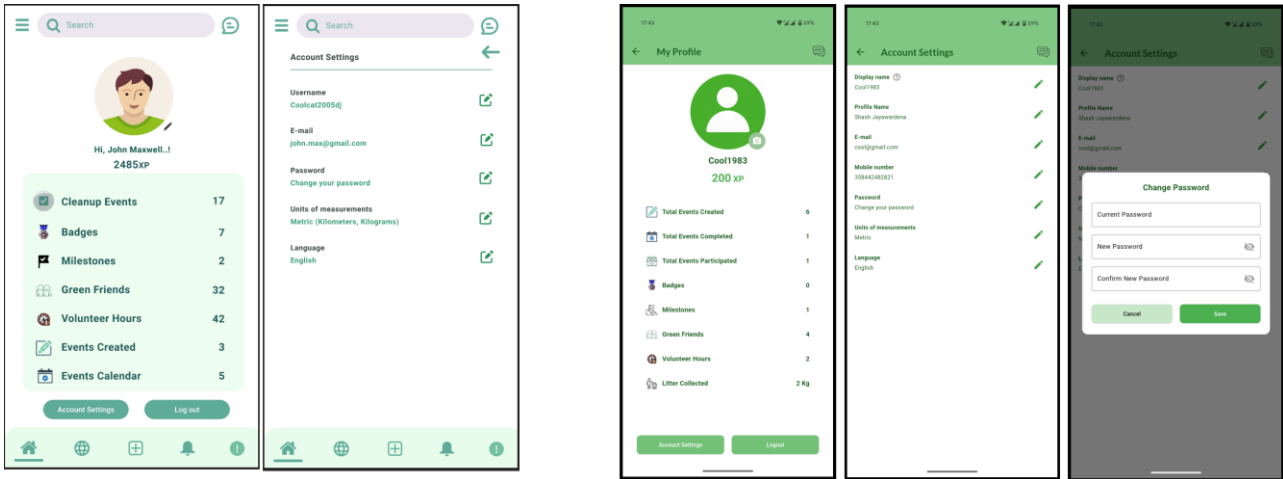


Figure 34. User Profile and Account Settings Screen Comparison.

Figure 35 illustrates the My Events section (upcoming events and completed events), where users can edit, delete, or mark as complete an event screen, event edit screen, completed event data input screen, and completed event details screen.

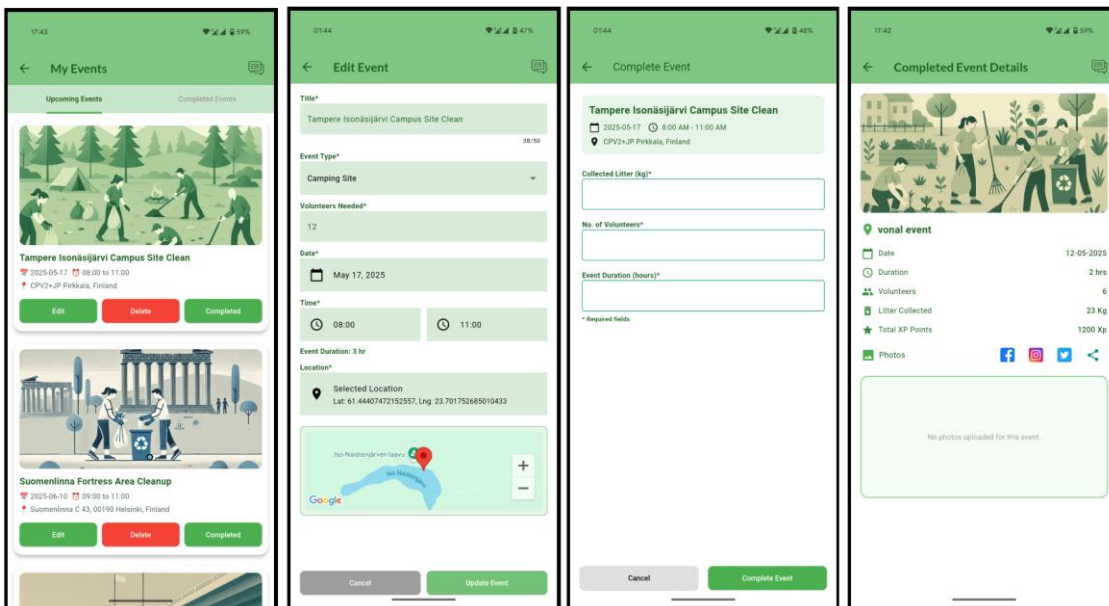


Figure 35. My Events Section Showcasing Upcoming and Completed Events, Including Event Editing, Deletion, Completion, Data Input, and Full Details Screens.

Following Figure 36 illustrates the upcoming event details screen comparison. This screen has undergone only minor changes, with the overall layout and structure remaining largely the same.

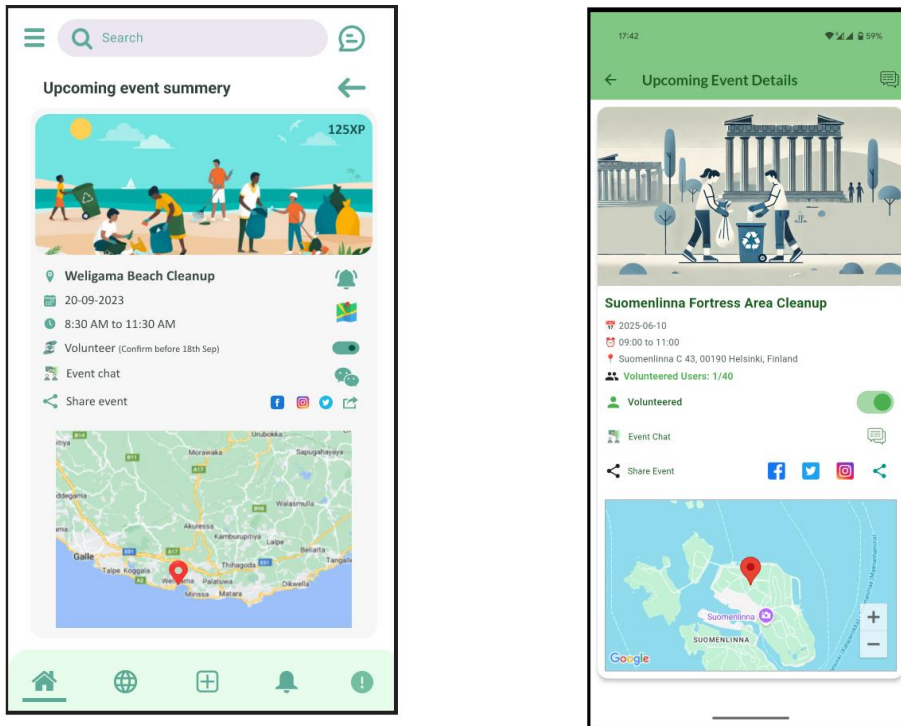


Figure 36. Upcoming Event Details Screen Comparison.

In Figure 37 below, the actual app screen of the Green Friends section illustrates the contacts list showing which users are already using the app and which are not. For contacts who are not using the app, the screen provides an option to send invitations directly. Additionally, a sample screen of the event-dedicated chat highlights the importance of having a built-in chat feature to coordinate activities related to the event successfully.

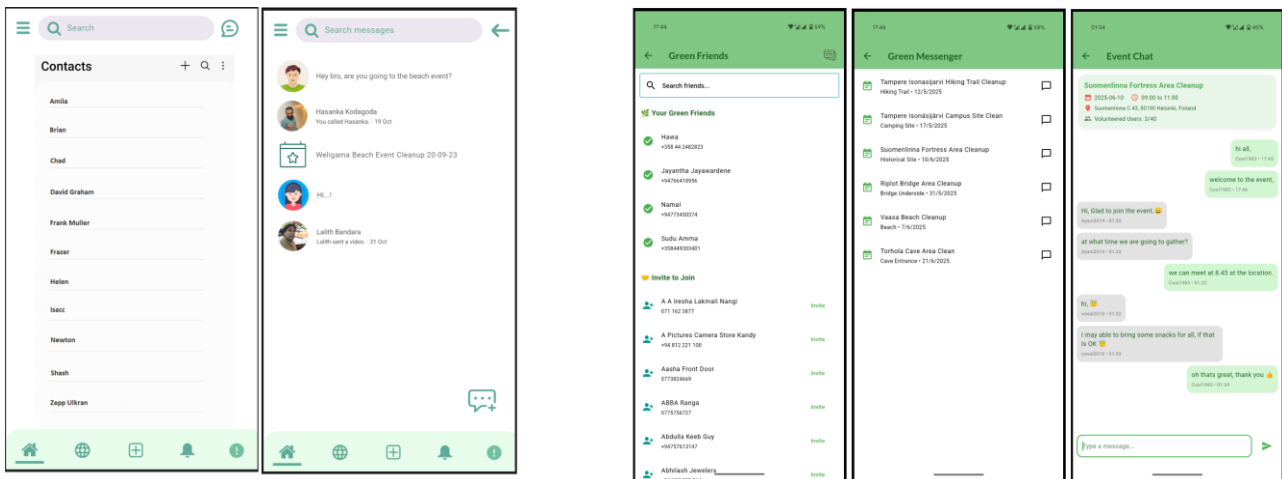


Figure 37. Green Friends, Chat, and Sample Event-Dedicated Chat Screens Comparison.

5.2 Overview of Evaluation Process

The early evaluation process of the Green Savers app was carried out using structured validation methods using the categories of usability, aesthetic feel, and functionality of the app. This process is executed by providing a Figma prototype for survey participants to access remotely and provide feedback through a well-structured online survey. The overall evaluation was carried out in two phases.

1. **Prototype Evaluation:** The participants explored a high-fidelity, full-featured prototype mimicking core features such as event creation, chat, user profiles, leaderboard, news articles, gamifications, and knowledge center. Their experience and suggestions were captured through a survey that covered all the sections, such as navigation, accessibility, layout, content relevance, and overall user satisfaction.
2. **Feedback Integration in Development Mode:** After carefully analyzing user feedback, based on the quantitative and qualitative data, redesigned the application flow and then applied refinements to the UI, navigation structure, and feature layout. Using Agile methodology, iterative improvements were applied to the mobile application.

This 2-step evaluation allowed identifying strengths and weaknesses of the solution in early stages and then preparing, fixing, and applying to the final version. Ultimately leading to the final implementation reflecting user-centered design principles.

5.3 Analysis of Survey and Testing Results

The survey results revealed very strong positive feedback, giving clues that the app has great potential. Most of the participants rated the app as aesthetically very appealing and easy to navigate. Also participants highlighted gamification elements such as milestones, badges, and leaderboard that will motivate users to engage frequently in events and help long-term engagement with the application. Additionally, appreciated the map integration, real-time chat, and knowledge center features. Qualitative feedback greatly helped in improving some of the existing features and suggested valuable future integrations such as theme customization, personalized profile sections, multilanguage support, and better onboarding guidance.

Below mentioned key analysis points revealed highly encouraging results from the prototype testing,

- **Navigation and Usability:** Over 60% of participants found that navigation is very easy.
- **UI Appeal:** Most of the users really liked the aesthetic feel of the app.
- **Highest Rated Features:** Event creation, map integration, chat feature, and gamification features such as milestones, badges and XP.
- **Social Features:** 68% of participants found that social media integration is excellent. Because they can share achievements and promote events.
- **App Satisfaction:** More than 85% of the users rated overall app satisfaction 4 or 5 out of 5. This proved that the app's core concept is meaningful and aligns with user expectations.
- **Suggestions:** Users requested dark mode and additional profile customizations such as adjustable font size and multi-language support. Also, requested donation integration, better onboarding, help guide for new users, and more broad communication tools.
- **Willingness:** More than 75% of participants confirmed that they will download the app once it will go live, not only that 80% of users mentioned that they will recommend this app to friends, family, and community.

These findings confirmed that the app perfectly serves its purpose by providing a collaborative environmental conservation platform.

5.4 Practical Limitations and Application Results

Even though the app's core features are successfully completed, it had to face the below mentioned limitations.

- The app is still not published on any platforms such as Google's Play Store or Apple's App Store.
- Testing was done only using a prototype, not a fully developed app with real-time interactions.
- Limited user survey: The survey size was only limited to 39 participants. This could not reflect broader community opinions and suggestions.

However, even with these limitations, the application successfully demonstrated its potential within the tested user community.

5.5 Limitations of the Study

The study had some limitations. The survey was limited to 39 participants, and most of them were IT professionals. Therefore, results may not fully represent environmental volunteers or the majority of general users. There were some of the prototype constraints as well, such as the prototype lacking the backend integration and not being based on real-world event conditions. Additionally, there were some geographical limitations. Because most of the participants are from the Asia region. This may not reflect insights of a global scale.

5.6 Future Research and Enhancements

Although the Green Savers app is currently equipped with fully functional core features such as event coordination, statistics, profile customization, news articles, milestones, and a knowledge center, several future improvements are planned to build the app's trustworthiness, community value, and motivational appeal.

To keep and build the app's reputation, the primary concern is to prevent fraudulent behaviours such as creating fake events or falsifying completing them in order to achieve milestones, badges,

and possibly climb the leaderboard. Additionally, features such as external partnerships, more social features, and individual-focused tools are also planned to be introduced into the Green Savers app. This action will not only boost motivation and long-term engagement of the users but also foster authenticity and real-world impact.

5.6.1 Planned trust and Anti-Fraud Measurers

- GPS Based Location Verification via Photo Uploads: This requires users to physically be at the event during the event duration and mandatory geo-tag-enabled photo uploads (via in-app camera or gallery) as proof of actual cleanup. Optionally timestamped and stored in Firebase Storage.
- Participant Rating System: Enable user rating feature for every event and event creator. That way volunteers can give ratings and possibly upload multimedia files and validate the event and event creator.
- Users Own Reputation: With a new badge called “Green and Verified”, award honest and active users based on the reputation they gained. This will ensure and boost the reputation of both the app and users.
- Minimum Volunteer Threshold: Require at least 2-3 volunteers for an event to be completed.
- Cool-down Timers: Introduce a time buffer between event creation and completion to prevent rapid event completion.
- Limited Event Creation: The maximum ongoing number of events will be limited to 2 per creator. This will limit the fake event creation without completion.
- Report and Flag Mechanism: Event reporting mechanism for reporting questionable events (places impossible to reach, like in the middle of a lake or ocean, mismatched event title and event location and events where no one showed up at the scheduled location) or completions.
- Validated Rewards System: XP, badges, and milestones only issued upon the verification of all event pass checks.

5.6.2 Partnerships and Motivational Features

- Sponsoring partnerships: Collaborate with eco-friendly brands and NGOs to sponsor cleanup events to provide equipment, snacks and drinks, or even reward participants.
- CSR Collaborations: Allow organizations to partner with Green Savers for initiating Corporate Social Responsibility (CSR) events and reward volunteers.
- Discounts on Eco-Friendly Products: Provide the facility to buy eco-friendly products and services with a discount.
- Digitally Signed Certificates: Issue verifiable, digitally signed certificates for participation in events. Volunteers can use these in their CVs, social media, or any other professional portfolios, such as LinkedIn.
- XP-Based User Promotions and Authorities: Using XP levels gained over time, introduce a user level and assign roles in the app as motivation and appreciation within the community. Below, Table 3 describes the proposed user level and their role.

Table 3. Proposed User Levels and Description

Level Name	XP Range	Role/Permission	Description
User	0-999	Basic app features	Default level for new users
Activist	1000-2499	Can moderate events, manage volunteers	Trusted participant with growing involvement
Moderator	2500-4999	Assist with event report/flag	Trusted for maintaining quality in the app
Eco Ambassador	5000-9999	App promotor	High level contributor
Admin	10000+	Full Control	Reserved for developers or top tier users

5.6.3 Social and Individual Engagement Tools

- Individual Cleanup Mode: Introduce a dedicated section for users who still prefer to work alone. They can report solo cleanup efforts, submit proof, and track their individual efforts on environmental impact.
- Social Feed Page: Create a social feed page to share users' achievements, opinions, suggestions, event participation multimedia, and event statistics to foster inspiration and community connection.

5.7 Challenges Faced and Solutions

In the process of designing to development of the Green Savers application and writing the thesis presented various challenges. Most of the challenges were able to be solved with self-learning and extensive searching on the internet. Even though at some points had to get help from some AI tools and professional support.

One of the earliest challenges was using the Figma tool for designing the application. The author has no prior experience in this regard. But after exploring the Figma tool for a few hours and with YouTube tutorials, it became easy to design the app prototype. In the stage of the research phase, a wide range of environment-related mobile applications had to find, install, and used. This process helped to understand each application's strengths and weaknesses. For the part of the application flow and understanding UX/UI patterns, several popular social apps were explored.

Similarly, the developing application stage was an entirely new experience. It was the first time the author worked with the Flutter framework. Before starting the project, the author followed many YouTube videos and a set of Flutter tutorials as a startup and for self-learning. Still, during the development stage had to face difficulties and complex tasks such as reverse geocoding, state management using Riverpod, and other advanced Flutter features. Debugging and testing on emulators and physical devices was a time-consuming process since all the tasks were handled by the author. There were countless design iterations carried out as a result of testing feedback. There was a moment that the author had to seek help from a professional Flutter developer to solve a specific but essential feature of the application.

Collecting feedback for the user survey was also another challenge. The author had to contact and remind participants several times through phone calls, reminders, and follow-ups to ensure participation and completion. When accessing recent scholarly articles for literature review, had to face many paywalls limiting access to freely available up-to-date research materials.

Use of AI Tools: In this project author used artificial intelligence tools many times in app development process and documentation. The ChatGPT tool was used many times in debugging Flutter errors, suggesting alternative solutions, explaining technical concepts like Riverpod state management, and assisting in refining the documentation content. The GitHub Copilot tool also

helped a lot to speed-up the coding process by providing real-time code suggestions and automatic error fixes. The Grammarly tool is also used in thesis writing to fix grammar issues and improve the overall readability of the text.

5.8 Ethical Analysis and Reliability

This research was carried out according to the guidelines set by JAMK University of Applied Sciences and the European Union's General Data Protection Regulation (GDPR). Before conducting the survey, all participants were informed and obtained consent from them. Participants were clearly made aware that the survey was solely used for academic purposes in this master's thesis. Also it clearly mentioned that personal data was not shared with third parties at all.

The secured Google Forms platform was used to design questions and collect data from the user survey. Participation in the survey was voluntary, and all responses were collected anonymously. Google's built-in security measures ensured encrypted data transmission and safe handling of participant data. To maintain data authenticity and avoid duplicate entries, an email address was collected from the participants and used as a unique identifier. Additionally, the survey was only offered once per participant to maintain the response validity.

Access to collected survey data is strictly limited to the author and official academic advisors if required. No third-party or unauthorized individuals were allowed to access data at any point. As mentioned previously in the survey introduction, all personal data and responses will be deleted as soon as the thesis project is officially completed and evaluated.

Overall, the collected data was verified and considered trustworthy and sufficient for continuous improvement and development of the Green Savers application. To maintain the integrity and reliability of the research study, ethical considerations and data protection principles were respected and followed.

6 Conclusions

6.1 Summary of Research and Development Process

This project began with identifying a missing gap that supports environmental conservation through community engagement. The early stages focused on understanding the user requirements of the community, exploring the current environmental mobile app solutions, and conducting the background research. A mixed-method research approach was used on the user survey to capture both quantitative and qualitative data through an online questionnaire, including open-ended questions based on the Figma prototype. These findings helped to understand the feature set and further design direction of the Green Savers application.

Then the application development process started with the Flutter framework for the front-end and Firebase service for the back-end of the application. The applications core features, such as event creation, location tracking, user statistics, chat features, and gamification elements (XP, milestones, badges), were implemented. During the development, usability testing was conducted on both emulators and physical devices to ensure the functionality and user satisfaction.

Despite facing several challenges such as technical limitations and time constraints, the project remained focused and able to complete fully working app with core functionalities aligning with user requirements and research findings.

6.2 Key Takeaways and Contributions

At the end, this thesis and development process pointed out meaningful outcomes and learnings. Firstly, it clearly highlighted the importance of user-centered design. App features were designed by an experienced user (the author) in the environmental conservation community. Then shaped and refined by another set of environmental activists and potential users. The iterative design process makes sure that the app remains and polished by user needs and expectations.

The winning key contribution of this project is the Green Savers app itself because, as of now, there are no or any other apps solely designed for gathering community members for environmental clean-up events. Most existing apps focus on very narrow aspect(s), such as

individual cleanup efforts, some focus on only oceanic activities, or general volunteering. This project clearly fills the gap by offering dedicated space for users to organize, join, and track litter collecting activities, making it a unique solution. Because of that, this app holds a strong potential to grow in the community of environmental conservation and potentially make a global impact on the nature.

This app integrates gamification elements (XP, milestones, badges) and real-time statistics to motivate users to engage in activities frequently. Also, social features like in-app chat facilities and green friend connections enhance the bond and collaboration within the community.

From a technical perspective, this app makes an example of Flutter and Firebase usage for building a cross-platform solution. It also highlights the proper use of modern tools like ChatGPT, GitHub Copilot, Figma, and Grammarly.

In summary, this application successfully combines environmental awareness, community engagement, and technology into a single solution, addressing most important and scalable model for future development.

6.3 Exploitation and Broader Significance

The Green Savers application has many potential factors beyond being just a mobile application. The app enables civic engagement in environmental efforts while creating social value and accountability. The app serves as an environmental education tool and promotes sustainability goals 11, 12 and 14. Which is “sustainable cities and communities”, “responsible consumption and production”, and “Life Below Water” respectively, created by the United Nations. Not only general individuals, NGOs, schools, and municipalities could use the app to mobilize communities, track progress, and organize local events.

6.4 Ideas for Further Development

Even though core features of the applications are completed, some of the essential topics and models were left. Future development needs to focus on features such as donation support, advanced fraud prevention, multilingual interface, and community discussion spaces. Also

suggesting, improve accessibility by providing a facility to change font size and themes. Additionally, suggesting to include a dedicated space for solo cleanup attempts. Apart from the existing motivation elements such as gamification, suggested user levels and user role promotion based on the experience they gain over time and offering digitally signed certificates to event participants as appreciation.

6.5 Personal Learning and Growth

To the author, the entire project was a fresh learning experience. Especially when it is coming to the development of the Green Savers application, combining both practical experience and theoretical knowledge was a valuable learning experience. Most importantly, this project enabled to show the full range of skills the author acquired during the master's degree programme at JAMK University. Knowledge gained from subjects such as user-centered design, modern software development practices, application frameworks, data modelling, and back-end development was mainly applied during the development of this mobile application solution.

As a summary, the thesis project was able to enhance the author's skills in especially,

- Mobile App Development: In Figma (UI), Flutter (front-end), Firebase and services (back-end), and app architecture.
- UX Research: Polished and gained real-world experience in user-centered design and usability testing.
- Project Management: Honed experience in planning, execution, applying Agile methodologies, and execution of iteration cycles.
- Environmental Insight: Acquired deep understanding of environmental challenges and digital involvement.

Ultimately, this journey extended and strengthened the author's technical and analytical skills while demonstrating how technology can be aligned with personal values and social needs to deliver meaningful and impactful solution to the world when it is needed most.

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Appendices

Appendix 1. Full Survey Questionnaires

Green Savers - User Experience & Environmental Conservation Survey.

Introduction

Thank you for taking the time to participate in this survey. This research is part of my master's thesis, which focuses on developing *Green Savers*, a mobile application designed to engage individuals and communities in combating environmental pollution. The application provides facilities to organize and participate in cleanup events at polluted areas. Application aims to provide seamless event creation, real-time communication through event-specific group chats, and a gamified experience with points and badges to encourage active participation. *Green Savers* aims to make environmental conservation more accessible and engaging, fostering a global community of eco-conscious individuals.

Before proceeding, please access the app prototype via the link below. After exploring the prototype, kindly complete the survey.

[App Prototype \(figma.com\)](#)

Note: Some elements of the app prototype are still under development.

Data Confidentiality & Privacy Assurance

Your privacy is important to us. All responses will remain confidential and will be used solely for academic research purposes. All the collected personal information retained only until the thesis is completed, after that will be permanently deleted. I will not share your personal data with any third parties. Access to your information will be strictly limited to myself and my academic advisors and assessors.

Your participation is highly valued, and your insights will contribute to shaping a meaningful solution for environmental conservation. Thank you!

Section 1: Personal Information

- Name
- What is your age group?
- What is your gender?
- Which continent is your country located in?
- Please select the field that most accurately represents your professional or personal affiliation
- Do you actively participate in environmental activities or initiatives?

Section 2: App Usage and Experience

- How would you rate the navigation between different interfaces?
- How would you rate the user interface and design of these pages?
- What features of the "Green Savers" app do you like the most? (Select all that apply)
- What features do you think need improvement or could be added to enhance your experience? (Select all that apply)
- Do you find the app's content relevant to your interests and concerns related to environmental conservation?
- How informative do you find the app's content related to eco-friendly products and nature preservation?
- Do you find the gamification elements (experience points, badges, milestones) motivating and enjoyable?
- When the app goes live, what will be your primary use for the app?
- On a scale from 1 to 5, how satisfied are you with the Green Savers app?

Section 3: Social Media Integration

- How important is social media sharing to you in an environmental app?
- Would you like to see more social integration features within the app, such as the ability to share your achievements or cleanup events on social media?
- Which one(s) do you like most related to the social media integration in the app?
- What are the other social integrations you would like to see in the app?

Section 4: Improvements and Suggestions

- What are the five most important features of an app that, in your opinion, make it easy to use and navigate?
- Do you believe that the "Green Savers" app incorporates any of the previously selected features?
- With the existing features in the app, how can we make the app more user-friendly and engaging for you?
- What additional features do you believe are currently missing in the app that could further enhance user engagement?
- When the app goes live, will you download and use the Green Savers app?
- Would you recommend this app to your friends, family, and community?

Section 5: User Experience on Environmental Conservation

- Have you ever participated in an environmental cleanup event?
- Have you seen similar mobile apps before which support environmental conservation efforts?

Section 6: Users' Environmental Conservation App Experience

- Have you used any mobile apps that support environmental conservation efforts?

Section 7: Other Environmental Conservation Apps

- Which of the following environmental conservation app(s) have you used or are currently using?

- What specific features do you like about the other apps you've used?
- How does the Green Savers app compare to these apps?

Section 8: Final Thoughts

- Do you have any final thoughts or suggestions for improving Green Savers?

Thank You Note

We sincerely appreciate your time and valuable thoughts. Your responses will help shape the development of Green Savers and contribute to meaningful environmental conservation efforts. If you have any questions or would like to receive updates on the research, feel free to reach out. Together, we can make a difference!