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Master's Thesis
Academic Year 2025

Sproute: Designing a Low-Carbon Lifestyle Application Based on Gamification Design

Keio University
Graduate School of Media Design

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A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

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Abstract of Master's Thesis of Academic Year 2025

Sproute: Designing a Low-Carbon Lifestyle Application Based on Gamification Design

Category: Design

Summary

Global warming and carbon emissions are critical global issues, and personal behaviors play a direct role in contributing to them. However, many people lack awareness of their carbon footprint and struggle to maintain long-term low-carbon habits. This study designs a gamified application that promotes sustained low-carbon habits and encourages behavior change. Unlike existing apps that rely on material rewards, this design focuses on emotional engagement by linking virtual achievements to real-world environmental actions. Users complete tasks to earn "point," which are used to grow a virtual tree that can eventually be planted as a real tree in their community. The app combines task completion, virtual tree cultivation, and light social interaction to connect personal behaviors with visible environmental impact. Using the Octalysis Framework and user workshops, the study identifies core motivational drivers such as Epic Meaning, Social Influence, and Loss. In addition to motivational mapping, behavior change observation and post-workshop survey were conducted to examine changes in users' real-world actions. Findings indicate that gamification design can support sustainable lifestyle changes, reinforcing environmental awareness through emotional and behavioral engagement.

Keywords:

gamification design, low-carbon lifestyle, octalysis framework, user motivation

Keio University Graduate School of Media Design

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Chapter 1
Introduction

1.1. Research Background

1.1.1 Global Warming and Carbon Emission

Climate change driven by global warming has become one of the most critical global challenges. The *Global Warming of 1.5 ^{o}C*, published by the Intergovernmental Panel on Climate Change (IPCC) in 2018, warns that if global temperatures rise by more than 1.5°C, the frequency and intensity of extreme weather events will increase significantly, posing serious threats to human society, ecosystems, and economic development [1]. In recent years, various regions around the world have experienced frequent climate-related disasters. During the summer of 2022, the Yangtze River basin in China experienced 79 consecutive days of extreme heat, with temperatures above 40 ° C affecting more than 1.029 million square kilometers. Wildfires occurred in Chongqing and other regions due to prolonged heat and drought[1]. In the United Kingdom, the summer of 2022 saw record-breaking temperatures reaching 40.3°C, severely affecting agriculture and urban infrastructure. In 2023, Phoenix, Arizona experienced 31 consecutive days with temperatures above 43°C, setting a new historical record.

These extreme climate events underscore the urgency of addressing global warming, with carbon emissions being one of its core driving factors. Carbon dioxide (CO_2), the primary greenhouse gas, is closely related to human activities, with major sources including electricity and heat production, industrial processes, transportation, and household energy consumption [2].

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1 National Climate Centre, `http://www.ncc-cma.net/channel/news/newsid/100053`, accessed May 12, 2025

In this context, governments around the world are actively implementing carbon reduction policies. For example, during the Japan–China High-Level Economic Dialogue held on March 22, 2025, both sides reached twenty key agreements, with the first emphasizing green development cooperation—specifically strengthening policy dialogue on carbon reduction and promoting green trade and investment[2]. In 2022, the United States passed the Inflation Reduction Act (IRA), regarded as the most significant climate legislation in U.S. history. The act aims to reduce greenhouse gas emissions by 40% from 2005 levels by 2030. These efforts reflect the growing global commitment to low-carbon and sustainable development.

1.1.2 The Impact of Human Carbon Emission Behavior

Discussions on global climate change often revolve around industrial emissions and government policies. However, individual behavior also plays a critical role in contributing to carbon emissions. The Consumer Lifestyle Approach (CLA), emphasizes that personal consumption choices and daily habits directly influence energy use and carbon output [3]. From multiple perspectives, individual low-carbon behaviors are essential for achieving sustainable development.

Although environmental sustainability has gained increased public attention, actual consumer behavior often falls short of low-carbon standards. In addition to factors such as price sensitivity and product quality concerns [4], barriers including a lack of information transparency and insufficient awareness of the environmental impact of personal consumption remain prevalent [5]. The SHIFT framework proposed by White, which identifies five psychological drives for encouraging sustainable behavior: social influence, habit formation, individual identity, emotional engagement, and perceived impact. These factors are key to motivating individuals toward adopting low-carbon lifestyles [6].

2 Ministry of Commerce of the People's Republic of China, `https://yzs.mofcom.gov.cn/zrjjgcdh/zxdt/art/2025/art_aa76ee48efdf414da0acb762b8738e62.html`, accessed May 12, 2025

1.2. Motivation and Goal

After arriving in Japan, I was deeply impressed by the profound impact that environmental awareness can have on the overall social ecosystem. Japanese residents generally demonstrate a strong sense of environmental responsibility, evident in the classification of waste, the adoption of clean energy, and the implementation of the SDGs in various sectors. These practices have not only created clean streets, clear rivers, and fresh air, but also shaped my belief that collective low-carbon behavior can significantly improve environmental quality.

Although China has made considerable efforts to promote low-carbon lifestyles, evident in government initiatives and public campaigns, the absence of clear, actionable guidance often limits their effectiveness. For example, proper waste separation remains challenging due to a lack of public awareness and consistent social norms. Many consumers are also unaware of how their daily consumption choices contribute to carbon emissions. In this context, a tool that guides and visualizes individual low-carbon behaviors is essential.

While several gamified applications have emerged in recent years to encourage low-carbon behaviors through mechanisms like point systems, virtual rewards, and leaderboards, most of these platforms rely heavily on extrinsic motivation. According to the Gamification Framework [7], these applications tend to emphasize left-brain drives—achievement and ownership—while neglecting right-brain drives such as creativity, social influence, and curiosity. Studies have shown that excessive reliance on external rewards may lead to the "overjustification effect," where initial engagement is high but long-term behavior change is unsustainable due to a lack of intrinsic connection [8].

The purpose of this study is to design a gamification-based application that promotes the long-term adoption of low-carbon behaviors. Specifically, the research seeks to strengthen users' emotional connection with environmental protection and to foster a sense of accomplishment through both virtual achievements and real-world environmental impact.

1.3. Research Question

This research aims to explore two key questions: how gamification can be used to motivate users to adopt and maintain low-carbon behaviors over time, and how virtual rewards can be transformed into emotional engagement and translated into real-world environmental actions. Addressing these questions will help guide the development of a more emotionally resonant and behaviorally effective low-carbon lifestyle application.

1.4. Thesis Structure

This thesis has five chapters. Chapter 1 introduces the background of global warming and carbon emissions, analyzes the impact of individual behavior on carbon emissions, and presents the research motivation and key research questions. Chapter 2 provides a literature review and discusses related work, including previous studies on low-carbon behavior, gamification, and the Octalysis Framework. It also evaluates existing low-carbon lifestyle applications. Chapter 3 focuses on design. It elaborates on the design concept, core functions, and gamification strategies of the proposed low-carbon lifestyle application. Chapter 4 presents the design validation process. It evaluates the effectiveness and user acceptance of the application through Kano analysis, workshops, and the Octalysis Framework. Finally, Chapter 5 summarizes the findings of the research and discusses the broader implications and potential impact of the design on promoting sustainable lifestyles in the future.

Chapter 2
Literature Review and Related Works

2.1. Low-Carbon Behavior

Low-carbon behavior is generally understood as the set of actions individuals take to reduce greenhouse gas emissions through everyday consumption and lifestyle choices. These actions aim to minimize personal carbon footprints, support sustainable development goals, and contribute to climate change mitigation. Low-carbon behaviors span multiple domains of daily life—for example, opting for public transportation over private vehicles, reducing household energy consumption, choosing low-carbon foods such as plant-based diets, and minimizing the use of disposable products. Such practices not only lead to direct reductions in CO_2 emissions but also encourage resource conservation and environmental protection by reshaping consumption patterns [9].

In *Low Carbon Lifestyles: A Framework to Structure Consumption Strategies and Options to Reduce Carbon Footprints*, the authors introduces a structured framework that categorizes low-carbon behaviors into four dimensions: direct reduction, indirect reduction, direct improvement, and indirect improvement. This model emphasizes the systemic nature of individual carbon-reduction strategies. Research suggests that while low-carbon behavior centers on reducing emissions through daily decisions, it is essential to consider both environmental benefits and potential trade-offs when designing effective carbon mitigation strategies [10].

The *Climate change 2014: mitigation of climate change* further highlights that behavior, lifestyle, and culture significantly influence energy use and associated emissions. It notes that reducing consumption, transitioning to sharing-based models, and adopting other behavior-driven changes hold high potential for emis-

sions reduction [11].

Despite the recognized potential of individual behavioral change in mitigating carbon emissions, existing low-carbon initiatives often face challenges in driving long-term user engagement and sustained lifestyle transformation. First, many interventions adopt traditional informational strategies or extrinsic incentives, which—while effective in raising awareness—lack the emotional resonance or feedback mechanisms necessary to foster intrinsic motivation. Second, most existing applications separate virtual behaviors from real-world ecological impact, creating a disconnect that diminishes users' sense of contribution. Third, emotional and social drivers—such as ecological identity, belonging, and friendly competition—remain underutilized in mainstream design approaches.

To address these gaps, this study proposes a low-carbon lifestyle application that integrates gamification strategies grounded in behavioral science. By linking virtual efforts to tangible environmental outcomes, incorporating emotionally engaging features, and enabling light social interaction , the design seeks to support both psychological engagement and habitual behavior change. This approach aligns with recent literature advocating for emotionally resonant, systemically integrated strategies that translate individual actions into meaningful climate contributions.

2.2. Gamification Theory

Ggamification was first introduced by British game designer Nick Pelling in 2002. It refers to the application of game design elements and principles in non-game contexts to enhance user engagement and overall experience [12]. Grounded in research on the characteristics of games and psychological theories, gamification leverages elements such as challenge, competition, and interaction to increase users' motivation and involvement. Common techniques include the use of points, badges, leaderboards, and rewards to drive participation, competition, and sustained interest [13].

Gamification is fundamentally a design approach centered on human motivation. As Yu-kai Chou explains, "Gamification is a design that places the most emphasis on human motivation in the process. In essence, it is Human-Focused

Design (as opposed to function-focused design)."[1]

2.2.1 Reasons Why Gamification Is Effective

Gamification mechanisms are commonly implemented through visual elements such as points, badges, and leaderboards (PBL), which constitute the foundational components of most gamified systems. Originally rooted in digital gaming, these elements have been widely adopted in non-game contexts to increase user engagement and promote targeted behaviors. The structural interplay between game mechanics and user experience creates dynamic feedback loops, wherein user behavior is shaped by—and simultaneously reinforces—the underlying gamified system [14].

Prior research has shown that these systems not only influence observable behaviors but also affect users' internal psychological states, fostering environmental awareness and motivation for real-world behavior change [15].

Nevertheless, insights from behavioral economics and educational psychology raise concerns about the sustainability of behavior change when it is driven solely by extrinsic incentives. The "overjustification effect" refers to a phenomenon in which external rewards for behaviors that are already intrinsically motivated may undermine internal drive. This issue is particularly relevant in sustainability contexts, where long-term behavior change depends on intrinsic motivation.

To address this challenge, gamification can be strategically designed based on the principles of Self-Determination Theory (SDT), which posits three core psychological needs: autonomy, competence, and relatedness [16]. For example, progress bars and performance feedback help satisfy the need for competence; social features like leaderboards or collaborative missions support relatedness; and customizable avatars and voluntary goal-setting enhance users' sense of autonomy. In contrast to financial rewards or static informational materials, gamified systems are intentionally crafted to foster internal motivation and long-term user engagement.

---

1 Yu-kai Chou, *The Octalysis Framework for Gamification & Behavioral Design*, `https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/`, accessed May 15, 2025

Furthermore, gamification allows for flexible design adaptations tailored to different user types. Prior research has identified four major motivational profiles within gamified environments: self-expression, reward acquisition, competition, and altruism [17]. Self-expression is supported through avatar customization; reward-seekers are motivated by point collection and achievement unlocking; competitive users thrive on leaderboards; and altruistic individuals are engaged through cooperative features such as gifting or group tasks. These engagement patterns align with cognitive biases like reward sensitivity and loss aversion, deepening users' emotional investment and behavioral persistence [18, 19].

Empirical studies have further demonstrated the advantages of gamification over traditional interventions. For instance, the BEACTIVE randomized controlled trial targeting individuals with high cardiovascular risk revealed that a gamified intervention increased participants' daily step counts by +1,954, slightly outperforming the group receiving financial incentives (+1,915) [20]. Likewise, Dahlström et al. [21] found that well-designed gamification elements significantly improved task enjoyment and intrinsic motivation in both educational and sustainability focused applications.

In contrast, traditional informational campaigns primarily aim to increase awareness by disseminating educational content through brochures, posters, advertisements, or seminars. While these methods can be effective for knowledge transfer, their capacity to generate sustained behavioral change remains limited. Studies have shown that purely cognitive approaches often fail to translate awareness into action, particularly in sustainability domains where habitual and emotional factors are influential. For example, Abrahamse et al. [22] conducted a meta-review of household energy conservation interventions and found that information-only strategies had mixed outcomes, often requiring feedback or goal-setting to be effective. Similarly, Schultz et al. [23] highlighted the critical role of social norms and personalized feedback in driving energy-saving behavior. These findings suggest that gamified systems—by incorporating interactivity, emotional engagement, and social comparison—can overcome some of the key limitations inherent in traditional one-way informational approaches.

2.2.2 Successful Applications of Gamification

Gamification is now widely regarded as a design approach that leverages game-based motivational mechanisms and interactive techniques to enhance user experience and influence behavior. Its application has expanded beyond traditional fields such as education, business, government, and social impact, and is increasingly being explored in areas like social interaction and sustainable development [24].

Duolingo, a widely-used language learning platform, provides a compelling example of successful gamification in practice. The app integrates core game elements such as points, daily streaks, levels, skill trees, and leaderboards to enhance user motivation and learning persistence. These features are strategically aligned with the principles of Self-Determination Theory—supporting autonomy, competence, and relatedness—thereby sustaining both intrinsic and extrinsic motivation. Empirical evaluations have shown that Duolingo's gamified structure contributes significantly to habit formation and long-term engagement. For example, the streak feature encourages daily participation by leveraging the loss aversion tendency, while leaderboards promote social comparison and healthy competition. Studies also suggest that gamified learning environments like Duolingo increase task enjoyment and reduce dropout rates, particularly among novice learners [25].This case illustrates how gamification, when implemented with psychological grounding, can drive sustained behavioral change in non-game contexts.

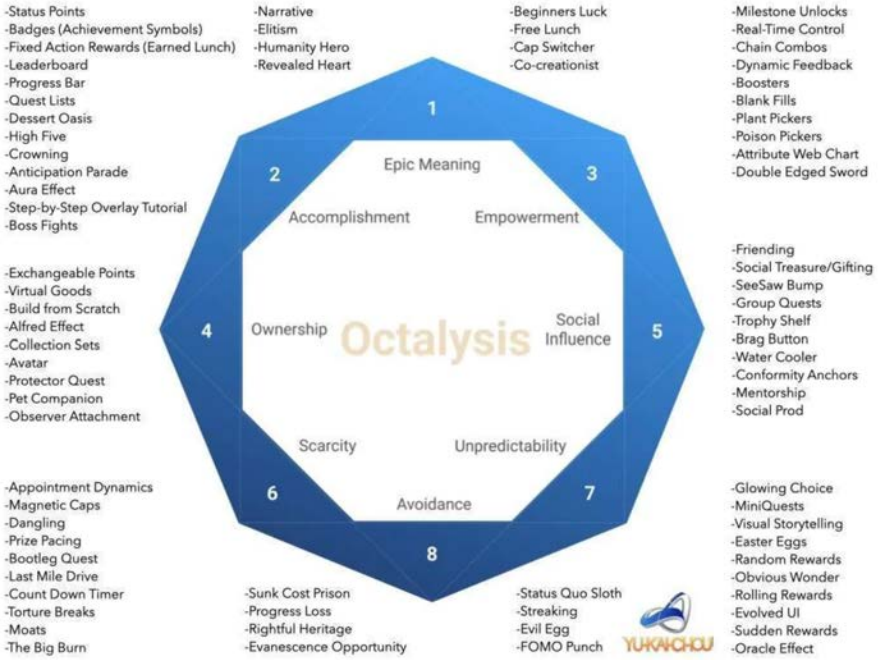
Table 2.1 summarizes some researchs of gamification applied in sustainability-related fields, illustrating the diversity of implementation strategies and research focus across these fields.

Table 2.1 Gamification Applications in Different Sustainability Fields

Application Field	**Gamification Mode**	**Relevant Literature**
Energy Consumption	Cooperation / Competition / Rewards	Ro et al. [26]
Sustainable Consumption	Competition / Rewards	Mulcahy et al. [27]
Driving	Competition / Rewards	Günther et al. [28]
Education	Cooperation / Competition	Gatti et al. [29]
E-commerce	Self-Presentation / Competition	Xu et al. [30]

2.3. Octalysis Framework

In book *Actionable Gamification: Beyond Points, Badges, and Leaderboards*, Yu-kai Chou introduces the Octalysis Framework, a gamification model that shifts focus from function-based design to human-focused design [31]. The framework outlines eight core drives that influence user behavior. These drives are widely applied in non-game contexts such as education, business, and sustainable development. Each core drive represents a distinct psychological trigger that, when effectively implemented, can enhance user engagement, motivation, and long-term participation.



(Source: Yu-kai Chou [7])

Figure 2.1 Octalysis Framework

1. **Epic Meaning & Calling:** Users are motivated when they believe their actions serve a greater purpose beyond personal gain. For example, some voluntarily contribute to forums or help build community infrastructure because they find meaning in the cause.

2. **Development & Accomplishment:** This drive centers on progress, skill acquisition, and achievement. Gamified systems often use points, badges, and leaderboards (PBL) to visually represent user progression, which reinforces a sense of competence and fulfillment.

3. **Empowerment of Creativity & Feedback:** Users enjoy the freedom to create and experiment, especially when they receive immediate and meaningful feedback. A well-known example is Minecraft, which gives players the freedom to build complex virtual worlds.

4. **Ownership & Possession:** When users feel ownership over items or progress—such as collecting digital assets or customizing their profile—they are more likely to stay engaged and protective of their investment.

5. **Social Influence & Relatedness:** Social factors like peer pressure, group collaboration, and friendly competition motivate users to act. Features such as friend comparisons, team challenges, and social rewards appeal to this drive.

6. **Scarcity & Impatience:** Limited-time items or exclusive rewards create urgency and desire. Users are more inclined to take action when they fear missing out on rare opportunities.

7. **Unpredictability & Curiosity:** Surprising or unexpected elements encourage users to keep engaging. For example, TikTok leverages this by presenting unpredictable content with every swipe, fueling user curiosity.

8. **Loss & Avoidance:** This drive stems from the fear of losing progress or missing benefits. For example, users who pay for monthly subscriptions tend to log in regularly to avoid wasting their investment.

2.4. Evaluation of Existing Low-Carbon Apps

This section reviews ten representative low-carbon lifestyle applications to understand the strengths and limitations of existing low-carbon apps. Each case

provides insights into how the gamification elements impact user motivation, engagement, and behavioral change. Among these, three applications are selected for in-depth analysis, the remaining seven are briefly introduced. The other evaluation tables are provided in **Appendix A** for reference.

Green Carbon Walk (China)

Green Carbon Walk is a mobile application promoting low-carbon travel and green lifestyles. It rewards users with digital RMB for participating in eco-friendly actions such as walking, biking, and using public transport. Advocating for the principles of "green travel, green consumption, and green living," the app aims to encourage widespread citizen engagement in sustainable behaviors.

In summary, Green Carbon Walk motivates users to participate in low-carbon actions through gamification and green travel incentives. Its digital RMB reward system and team challenge features enhance both engagement and retention. For this study, the app's gamification structure, collective challenge mechanisms offer valuable design references for behavior-driven sustainability applications.

(Source: Screenshots taken by the author from the Green Carbon Walk app)

Figure 2.2 Interface of the Green Carbon Walk application

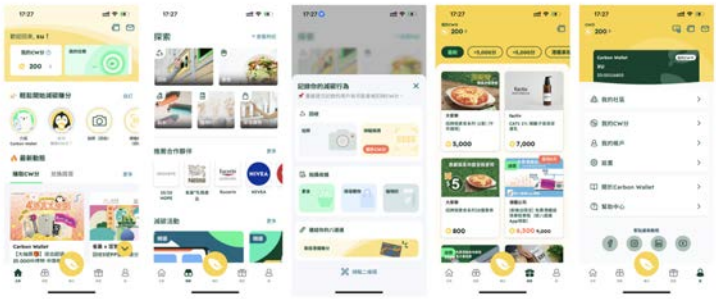
Table 2.2 Analysis of Green Carbon Walk

Analysis Dimension	**Description**
Core Function	Tracks low-carbon travel behavior and calculates carbon reduction; rewards users with digital RMB.
Tracking Method	Based on user activity records to compute carbon reduction.
Gamification Elements	Leaderboards, point redemption, challenge events, team competitions.
Emotional Connection	User interaction and team-based missions.
Virtual Achievement	Points, ranking, team victory.
Real Achievement	Digital RMB, public donations, or claim green products.
Advantages	Clear gamification structure, full feature coverage, direct incentive (RMB), team mechanics enhance engagement.
Notes	Currently region-restricted.

Carbon Wallet (China)

Carbon Wallet is a Hong Kong-based application that promotes sustainable living through gamified incentives. It tracks users' eco-friendly behaviors—such as recycling, public transportation usage, and green purchases—and calculates the associated carbon reductions. Users are rewarded with points that can be exchanged for environmentally friendly products or services.

Carbon Wallet effectively motivates users to engage in low-carbon living through gamification and multi-scenario eco-friendly actions. Its polar bear character and community interaction enhance emotional connection, and its user base and carbon reduction results demonstrate its success in the Hong Kong market. However, some users find the photo-based task completion process cumbersome. For this study, introducing character IP could further strengthen emotional connection, and adopting more convenient task interaction mechanisms could improve user experience.



(Source: Screenshots taken by the author from the Carbon Wallet app)

Figure 2.3 Interface of the Carbon Wallet application

Table 2.3 Analysis of Carbon Wallet

Analysis Dimension	**Description**
Core Function	Record environmental actions, calculate carbon reduction, and reward users with eco-friendly products or services.
Tracking Method	Based on user behaviors to estimate and track carbon savings.
Gamification Elements	Points, challenges, leaderboards.
Emotional Connection	Polar bear IP, community interaction.
Virtual Achievement	Points accumulation, leaderboard rankings.
Real Achievement	Exchange for eco-products, services, or support environmental projects.
Advantages	Engaging gamification design, comprehensive features, support for diverse eco-friendly behaviors.
Notes	Over 100,000 users.

Low Carbon Planet (China)

Tencent's Low Carbon Planet is a carbon management application that encourages users to adopt sustainable behaviors. The app tracks user actions, such as green transportation, mobile payment, and recycling, and converts them into measurable carbon reductions. Users accumulate carbon points, which contribute to low-carbon initiatives and public-interest environmental projects.

Low Carbon Planet records users' low-carbon behaviors, calculates carbon reduction, and rewards users with carbon points used in public-interest projects. However, its gamification elements are limited, and the lack of direct feedback or reward systems may hinder user engagement and retention. For this study, the app's "planet model" and humorous environmental content offer valuable strategies for improving emotional connection and alleviating the monotony often associated with sustainable behavior.

(Source: Screenshots taken by the author from the Low Carbon Planet app)

Figure 2.4 Interface of the Low Carbon Planet application

Table 2.4 Analysis of Low Carbon Planet

Analysis Dimension	**Description**
Core Function	Records low-carbon behaviors to calculate carbon reduction and generate carbon points.
Tracking Method	Tracks green travel using Tencent Maps to estimate emission reduction.
Gamification Elements	Points, carbon credit, leaderboard.
Emotional Connection	WeChat mini-program interactions, humor module.
Virtual Achievement	Carbon point accumulation and leaderboard ranking.
Real Achievement	Contribution to ecological projects.
Advantages	Broad user coverage, intuitive features, humor module adds engagement.
Notes	Nationwide reduction of 17.655 million tons CO_2 in 2022.

Ant Forest (China)

Ant Forest is a popular Alipay mini-program that encourages users to adopt low-carbon behaviors through gamification and environmental education. By recording eco-friendly actions—such as walking instead of driving, paying bills online, or using public transportation—the app generates "green energy" for each user. This energy is accumulated to grow a virtual tree, which is later converted into a real tree planted in desertified areas.

Ant Forest successfully motivates low-carbon behaviors through gamification and its large user base, with significant social impact and emotional connection. However, it does not visually display individual carbon reduction amounts, and users often lack a sense of initiative when tasks are completed unintentionally. For this study, Ant Forest's gamification mechanisms and social interaction features are valuable references.

EXPO Green Challenge (Japan)

EXPO Green Challenge uses the Osaka Kansai Expo as a platform to encourage businesses, schools, and local governments to take action toward reducing greenhouse gas emissions. By combining national policy with localized community campaigns, the program mobilizes a wide audience to participate in sustainability efforts.

EXPO Green Challenge attracts users through policy support and real rewards, aligning well with Japan's collectivist culture. However, since the Expo is time-limited, the application may struggle to retain users in the long term.

Reduce CO_2 (Japan)

Reduce CO_2 is a simple application designed to calculate users' carbon footprints and visualize the impact of their emission-reducing actions. It aims to enhance users' environmental awareness through clear data feedback and economic impact visualization.

Reduce CO_2 helps users track and reduce carbon emissions through a data-driven approach. Its clear data visualization and cost-saving features enhance environmental awareness. However, the lack of gamification and interactivity limits user retention, and its single-function design makes long-term engagement challenging. For this study, Reduce CO_2 provides valuable insights into behavior tracking and data feedback mechanisms.

Green Carbon Club (Japan)

Green Carbon Club is a low-carbon lifestyle application designed for residents of Kawasaki and the surrounding areas. It allows users to earn points by completing surveys, submitting low-carbon behaviors, and participating in environmental challenges. These points can be exchanged for eco-friendly goods. In addition, the app incorporates social features that encourage users to interact and share their environmental contributions.

Green Carbon Club motivates users through gamified participation and community engagement. The presence of a polar bear mascot and local campaign

features help foster emotional connection. However, the app lacks a clearly defined target user group, which may hinder its ability to maintain user engagement and long-term behavior change.

Commons (United States)

Commons is a widely used low-carbon lifestyle app in the United States that focuses on tracking users' carbon footprints based on daily consumption behaviors. It also provides actionable, sustainable suggestions to help reduce emissions. The app particularly appeals to younger demographics interested in eco-conscious living.

Commons effectively motivates users to engage in low-carbon living through consumption tracking and reward mechanisms. Its community interaction enhances user identification, while social media promotion increases its visibility. However, the app overly relies on consumption data and overlooks the potential of non-consumption behaviors (such as walking and reusing). For this study, combining broader behavior tracking could enhance emotional connection and long-term adoption rates.

JouleBug (United States)

JouleBug is a U.S.-based mobile app that promotes sustainability in the workplace by educating and motivating employees to adopt environmentally responsible behaviors. It is often used in corporate or organizational settings as a gamified tool to encourage teamwork around sustainability goals.

JouleBug encourages low-carbon behaviors through gamification. However, the lack of real-world feedback and long-term engagement limits user retention. For this study, the gamification mechanisms and community interaction of JouleBug are valuable references, but it is important to introduce deeper emotional connections to enhance the sustainability of long-term eco-friendly behaviors and user engagement.

Klima (Germany)

Klima is a German carbon offset application designed to help users reach personal carbon neutrality. It calculates individual carbon footprints with precision and offers subscription-based carbon offset programs. Users can also view real-time updates on the environmental projects they support.

Klima helps users achieve carbon neutrality through precise carbon footprint calculations and transparent carbon offset programs. Its user-friendly interface is another strength. However, the lack of gamification and long-term incentives limits user retention, and subscription fees and carbon offset controversies may impact its appeal. For this study, Klima's carbon calculation accuracy and project transparency are valuable insights.

Chapter 3
Design

Based on an in-depth review of literature on low-carbon lifestyle behaviors, gamification theories, and analysis of existing applications, this chapter proposes a design prososal for a low-carbon lifestyle application based on gamification design. The design aims not only to raise environmental awareness in users' daily behaviors but also to promote long-term engagement and positive behavioral transformation through a sustainable motivational structure. The interactive prototype of the application can be accessed via the following link: Sproute. For reference, this link is also provided in the Appendix.

3.1. Design Concept

3.1.1 Objective

This study aims to design an application based on gamification mechanisms to encourage users to engage voluntarily in low-carbon behaviors in their daily lives. The goal is to promote individual-level carbon reduction and enhance environmental awareness through sustained behavioral change. Unlike conventional approaches that rely on education campaigns or material rewards, this application seeks to foster a more interactive and emotionally engaging experience, making sustainable actions more tangible, attractive, and ultimately habitual.

Through a quantifiable point system, users' eco-friendly behaviors are translated into virtual rewards, allowing them to nurture a personalized "cyber tree" within the app. Light social features such as leaderboards and community comparisons create opportunities for social connection and mutual encouragement. In addition, anthropomorphized companion animals serve as motivational agents—providing

reminders, feedback, and emotional resonance throughout the user journey. When the cyber tree reaches maturity, users can plant a real tree in their community bearing a personalized nameplate. This establishes a symbolic and functional bridge between virtual engagement and real-world environmental impact.

3.1.2 Content

The application is named *Sproute*, a coined word combining "sprout" and "route." It symbolizes both the sprouting of a green lifestyle and the route toward letting such habits take root. This name reflects the core design philosophy of the app—growing trees through sustainable actions and reinforces the metaphor of environmental growth.

Figure 3.1 Logo of the application

Upon logging in, users are greeted by a friendly penguin character who guides them through a short questionnaire. This pre-task step helps users calculate their current carbon footprint, understand how it compares to others, and reflect on how their daily habits affect the planet. The aim is to spark motivation and create an emotional drive to initiate change.

On Task page, the app presents a variety of daily low-carbon tasks across multiple dimensions, including transportation, energy, waste, and recycling. Examples

include walking instead of driving, sorting waste, reducing plastic usage, and saving electricity. Both individual tasks and team-based tasks are available. When completion, tasks are converted into "Point" which are used to nurture a personalized cyber tree.

As point accumulates, users can see the growth of their virtual tree on Tree page, enhancing their sense of accomplishment. Once the tree reaches a mature stage, users can unlock a real tree planting opportunity in their community, with a personalized nameplate. An electronic certificate is issued to recognize their contribution, reinforcing the real-world significance of their actions. To enhance engagement, the app includes social features such as friend visits, where users can collect unclaimed point from others' forests. Additional elements such as leaderboards, point stealing, and pre-set message comments create a light social competiton, motivating ongoing participation. The presence of animal companions, like the penguin, panda and other mascots, serves not only as emotional support but also provides encouragement and feedback throughout the user journey.

The application also visualizes the environmental impact on My Page. Users can view total annual carbon emissions reduction, the equivalent kilometers of private car travel avoided, the amount of food saved, or the number of trees needed to absorb the same amount of CO_2 annually. This transparency helps users better understand the broader significance of their low-carbon behaviors and strengthens their motivation.

3.1.3 Target Users

The target users of this study are urban residents in China aged between 20 and 40, who are aware of environmental issues but often lack long-term behavioral motivation. They typically exhibit stable smartphone usage habits, are open to emerging digital experiences, and are inclined to engage with applications that offer emotional value or social interaction.

According to the *Statistical Report on Internet Development in China* released by the China Internet Network Information Center (CNNIC) in April 2024, as of December 2023, the number of internet users in urban areas reached approximately 790 million [32]. Among them, users aged 20 to 39 accounted for 62.8% of the total internet population. This group spends an average of 4.1 hours per day

on smartphones, actively engaging in social media, short video platforms, and various interactive mobile applications. These statistics indicate a strong reliance on digital platforms and a willingness to explore novel interaction formats, validating the design's focus on gamification and emotional engagement for promoting sustainable behaviors.

3.1.4 Innovation and Differentiation

Compared with existing low-carbon lifestyle applications, this study introduces several innovations aimed at fostering sustained behavioral transformation through gamification-driven design.

First, the application establishes a unique linkage between the virtual and the real—a "cyber tree to real tree" mechanism. As users accumulate energy points by performing eco-friendly actions, their virtual tree grows; once matured, it can be converted into a real tree planted in the physical world. This tangible feedback loop transforms abstract environmental efforts into visible, meaningful outcomes, significantly enhancing users' sense of achievement, environmental identity, and emotional commitment to low-carbon behaviors. The symbolic act of turning digital behavior into real-world environmental restoration serves as a powerful motivator rooted in both intrinsic value and prosocial impact.

Second, the application integrates anthropomorphic "guardian animal" characters that accompany the user throughout the experience. These characters function as interactive agents—guiding, reminding, and emotionally supporting the user along their low-carbon journey. This emotionally engaging element aligns with the gamification dynamic of "relatedness" from Self-Determination Theory (SDT), which has been shown to strengthen user loyalty and sustain engagement over time [33]. In contrast to rigid systems, this app adopts a lightweight interaction strategy. Features such as point sharing, leaderboard rankings, and one-click "likes" offer playful, low-barrier social engagement. These game elements harness social comparison and recognition without introducing excessive pressure, thus encouraging voluntary and joyful participation.

Third, the app promotes ongoing behavior change through the strategic use of visual feedback. Intuitive visualizations of environmental contributions—such as "kilometers of car travel avoided" or "amount of CO_2 absorbed by trees annu-

ally"—translate user actions into comprehensible environmental metrics. These metaphorical representations not only enhance users' perceived impact but also support sustained motivation by making long-term consequences feel immediate and tangible.

Importantly, this design leverages key gamification principles known to support behavior change. Elements such as progress tracking, personalized goals, and symbolic achievements are deeply rooted in gamified motivation dynamics—including achievement, ownership, and scarcity [31]. Unlike traditional low-carbon apps, the present system employs emotional design, symbolic transformation, and user-type–sensitive gamified features to foster internalized, sustained behavioral change. This holistic integration of gamification ensures not only repeated engagement but also a deeper psychological connection between user behavior and environmental responsibility.

3.2. Core Functions

This application is designed around a closed-loop model of "task-driven engagement, emotional connection, and real-world feedback." It introduces users to the background of global warming through posters and guides them to recognize their own carbon footprint using an interactive questionnaire. The app encourages users to take daily low-carbon actions through a gamified task system, with feedback provided via points and a visualized tree growth mechanism. Users can nurture their virtual trees, unlock guardian animals, and compete or cooperate with friends via social features and leaderboard. Additionally, the app visualizes users' environmental contributions with intuitive data representations and ultimately connects virtual behaviors to real-world tree planting. By combining gamificaction design, timely feedback, and emotional storytelling, the application transforms sustainable actions into engaging daily habits.

3.2.1 Interactive Questionnaire

Before beginning low-carbon tasks, users are guided through an interactive questionnaire to calculate their current carbon footprint. The design of this module is

informed by the internationally recognized carbon assessment model WWF [34], and evaluates the lifestyle habits of users in multiple dimensions.

A friendly penguin character leads the questionnaire experience, supported by illustrative visuals and contextual prompts that enhance approachability and engagement. Questions cover areas such as flying habits, dietary preferences (e.g., vegetarianism), annual driving distance, shopping habits, household electricity usage, recycling behavior, and water-saving practices. Once completed, the system automatically calculates the user's estimated annual carbon emissions (in tons of CO_2e) and visually compares it with the national and global averages per capita. The results page includes a motivational message: "Your choices matter — every small action shapes the planet's future."

These interfaces not only help increase users' awareness of their environmental impact but also build intrinsic motivation through a visually engaging, emotionally resonant experience that prepares them for the tasks of the application.

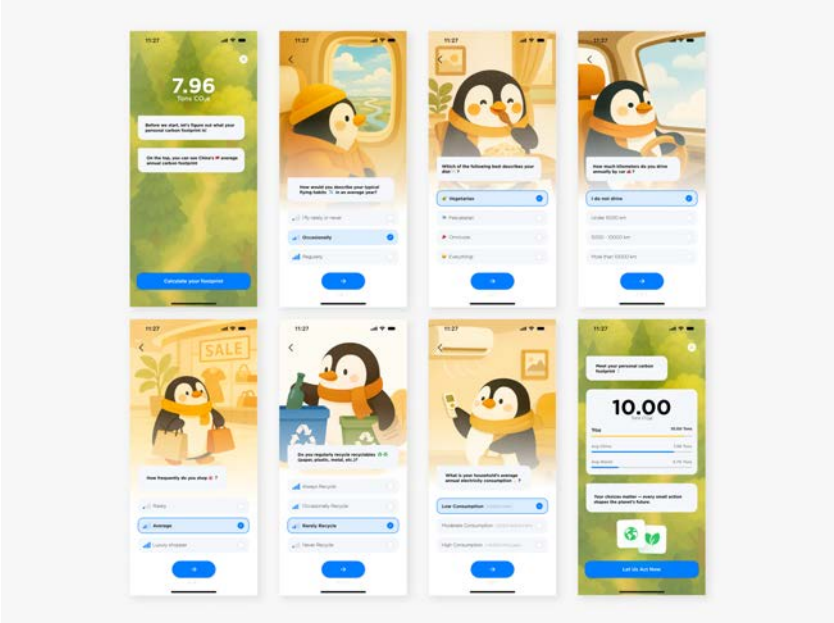


Figure 3.2 Interface of carbon footprint questionnaire

3.2.2 Daily Low-Carbon Task

The daily task system serves as the main interactive interface of the application, guiding users to develop sustainable habits while offering clear rewards and progress tracking. On the Task Page, users can view their weekly task progress. By tapping a task, users can access a detailed page that describes the task introduction, user's contribution, and which friends have also participated.

The tasks cover various aspects of daily life, such as "Walk instead of driving," "Take public transport," "Reduce single-use items," and "Sort waste." These tasks are designed to be easy to implement and environmentally meaningful. Upon completing a task, users slide a confirmation button to receive points as a reward. The feedback screen features anthropomorphic character animations that cheer for the user, enhancing the sense of accomplishment and emotional engagement. In addition to individual tasks, a "Team Challenge" feature allows users to collaborate with friends on team goals, such as "Reduce 50 single-use items together." Real-time progress and team contributions are displayed. Successful completion gives rewards to all team members, reinforcing teamwork and social participation. The app also includes a "Friend Invitation" function. When users invite others to join the mission, both parties receive bonus points and are automatically connected to the community. This helps build a social ecosystem around sustainable behavior and increases peer-driven engagement.

By integrating goal setting, progress visualization, immediate feedback, collaboration, and gamified incentives, the daily task system encourages users to gradually internalize low-carbon behaviors and transform them into long-term habits.

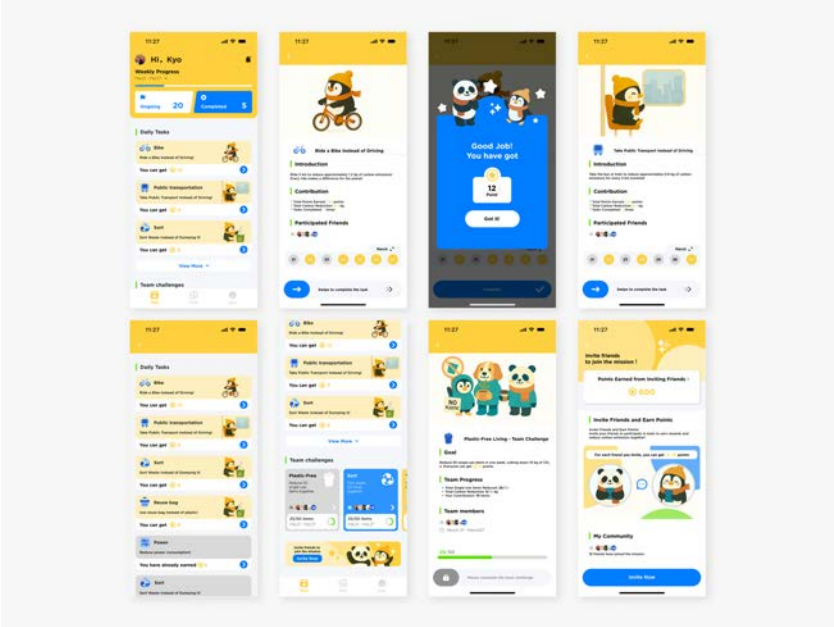


Figure 3.3 Interface of task

3.2.3 Virtual Tree Growth

The virtual tree interface is a core feature that fosters both a sense of achievement and emotional connection. Users accumulate points by completing tasks, points are used to nurture their personal virtual tree, which gradually grows from a seedling into a mature tree.

The growth process is visually presented with animated transitions that enhance users' sense of progress and immersion. As the tree grows, users can unlock different tree species, such as cypress and deciduous trees. Each species features unique visual designs, background stories, and educational facts that highlight its ecological value. Users can view their progress and compare it with others through the leaderboard, which displays each user's current tree status and accumulated points. Users can also visit their friends' pages to explore the trees they have grown, the point they have collected, and the guardian animals they have unlocked. If a friend has not logged in for some time or has unclaimed points, other users can temporarily collect the unused point as a gentle form of social

interaction.

This "unlock—nurture—showcase—feedback" system serves as a visual and emotional bridge between virtual rewards and real-world actions. It supports long-term user engagement by establishing a strong sense of responsibility and environmental belonging.

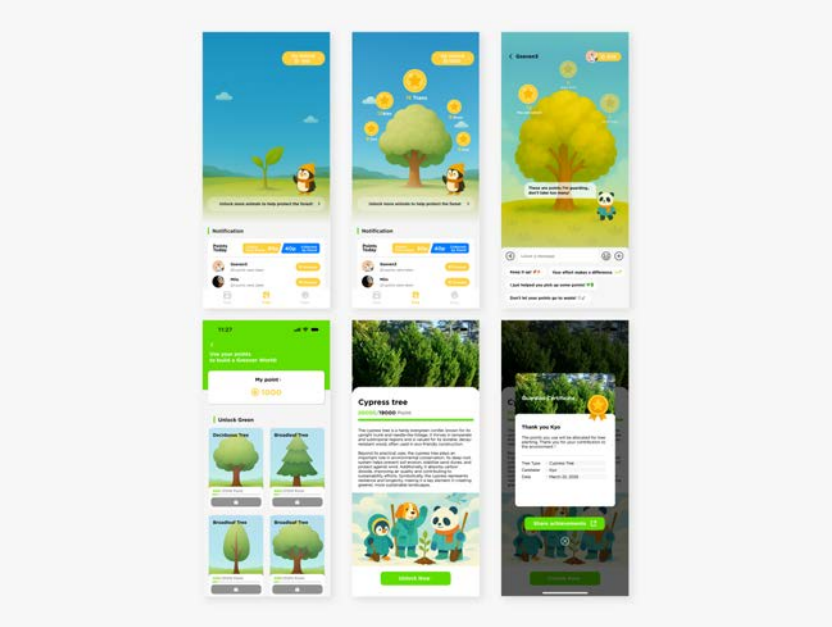


Figure 3.4 Interface of vitrual tree

3.2.4 Social Interaction

To enhance user engagement and encourage consistent participation, the app incorporates lightweight social interaction functions. These functions not only make low-carbon behaviors more enjoyable but also build a community around shared environmental goals.

The leaderboard ranks users based on their weekly accumulated points. Each user's profile picture is displayed alongside their score, allowing friendly competition among peers. Tapping on any friend's profile picture takes the user to that friend's tree page, where they can view their virtual tree growth and guardian animals. If a friend has not logged in for a long time and has not collected their

points, other users can "steal" the unclaimed point.

The guardian animal also appear with speech bubbles on the page, such as "These are points I'm guarding, don't take too many!" to soften any negative connotations associated with the interaction and to keep the tone friendly and playful. At the bottom of the page, users can leave quick comments using preset phrases like "Your effort makes a difference!" or "Don't let your points go to waste!" This encourages positive reinforcement and friendly reminders. Users can also send greetings or jokes to strengthen social bonds. The use of emojis and illustrated stickers makes communication more expressive and engaging.

On My Community page, users can view their friend list, including each friend's last activity and whether their point was collected by you. When point is collected, the action is shown in the message panel with a friendly, personalized graphic, such as "I just stole your 20 points!" This approach avoids negative feedback while introducing gentle pressure to stay active.

In conclusion, the social interaction functions in app focuses on visibility, light competition, and emotional connection, turning sustainable actions into shareable and socially supported behaviors.

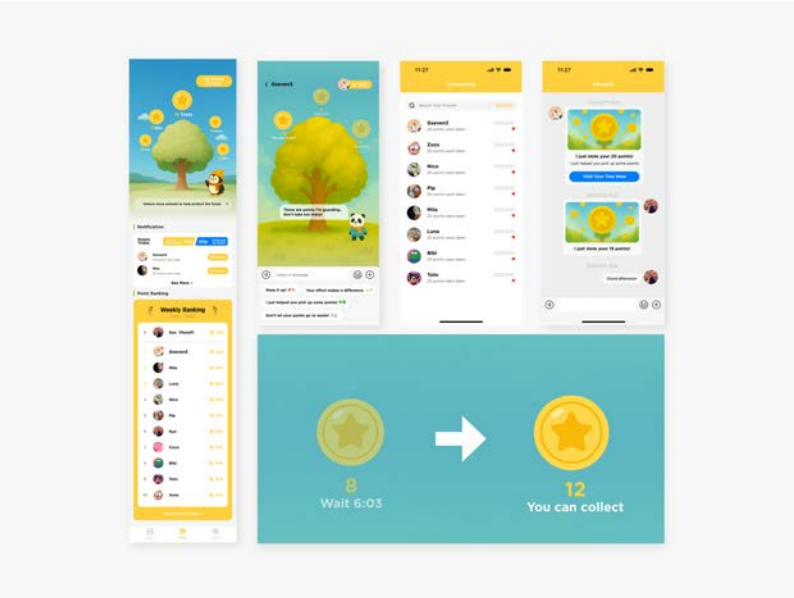


Figure 3.5 Interface of social function

3.2.5 Guardian Animal Companion

To enhance emotional engagement and interaction, the application introduces a companion system featuring "guardian animals." These virtual partners serve as motivational symbols, emotional feedback agents, and conversation starters in social features.

Users can unlock guardian animals by accumulating points through task completion. Characters include penguins, pandas, turtles, and polar bears, each representing a species affected by climate change. The unlock screen features information about each animal's current environmental challenges, promoting ecological awareness and responsibility. Once selected, the guardian animal accompanies the user on their tree page. When tasks are completed, the animal will smile in celebration. When visiting a friend's tree, users can also see their guardian animal. These shared characters provide a natural way to initiate conversations and foster shared experiences. For example, users might say, "You've switched to the turtle!" These interaction exchanges strengthen social bonds and increase the stickiness of the application.

This emotional design boosts interactivity and motivation and subtly delivers reminders and encouragement, making low-carbon engagement feel more like a relationship than a task list.

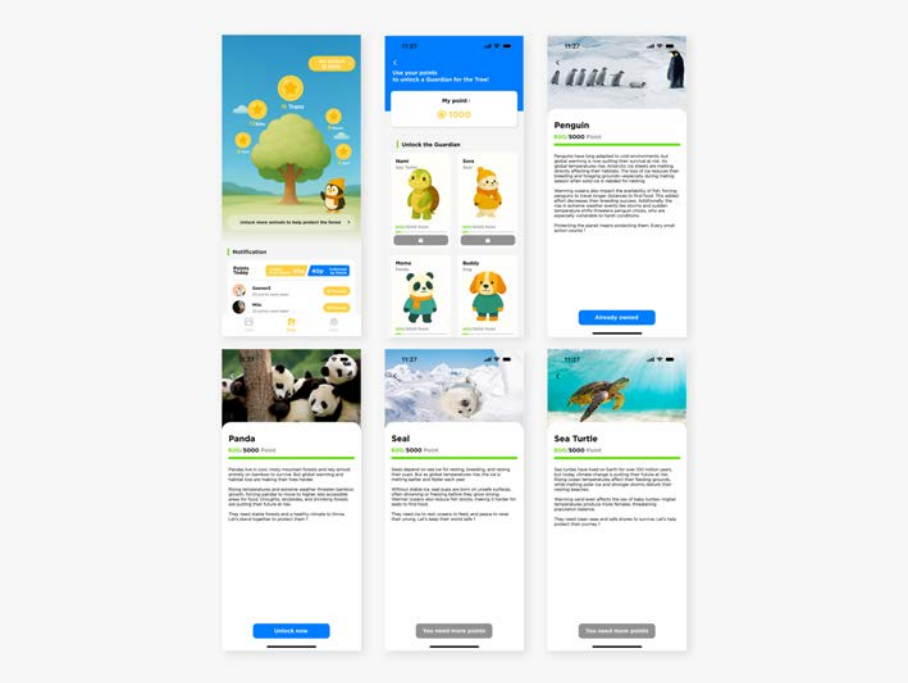


Figure 3.6 Interface of Guardian animals

3.2.6 Visualization of Environmental Impact

To help users clearly understand the real-world effects of their low-carbon behaviors, the application includes a visualization module that translates abstract carbon reduction data into intuitive and relatable metrics. This enhances users' sense of accomplishment and deepens their identification with sustainable practices.

The app displays the user's annual total reduction in CO_2 emissions. To contextualize this data, the system provides relatable equivalences such as "equal to not driving 366 km," "equivalent to planting 4.35 trees," or "offsetting a one-way flight from Tokyo to China." These comparisons are based on realistic environmental data and help users perceive the tangible impact of their behavior. A more detailed page presents the same carbon reduction effects through symbolic icons that represent familiar life scenarios—such as hamburgers skipped, phone charging sessions avoided, or household electricity saved. These icons do not re-

flect additional emissions avoided but offer alternative ways to visualize the same cumulative result, making the data more approachable and engaging.

By embedding visual feedback into the user experience, this module reinforces the idea that "every small action counts." It empowers users with a sense of measurable progress and fosters long-term motivation through visible, real-world significance.

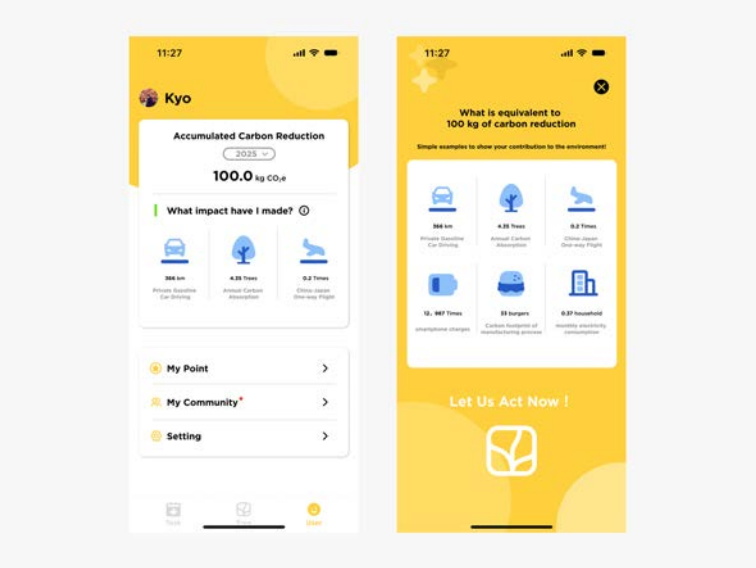


Figure 3.7 Interface of environmental impact

3.2.7 Real-World Impact

To extend virtual actions into meaningful real-world impact, the application incorporates a real-world tree mechanism. This feature connects users' accumulated points with actual tree planting initiatives, creating a closed-loop experience from digital behavior to tangible environmental contribution.

When a user's virtual tree reaches full maturity and sufficient points have been collected, they are eligible to unlock a real tree to be planted in their community. The tree will be marked with a personalized nameplate identifying the user as the contributor. In collaboration with local community partner Puluo Property, which operates a farm in Hengxi, Ningbo, pilot projects are currently in progress. The

property offers tree planting and other eco-agricultural activities for its residents, making it an ideal site for real-world environmental engagement.

Figure 3.8 Puluo Property's farm

The nameplate not only validates the user's environmental efforts but also enhances their sense of accomplishment and ceremony. A QR code printed on the plate allows others to scan, download and access the contributor's tree page, where they can view the user's tree growth, and guardian animal. This physical-to-digital bridge amplifies the tree-planting experience and promotes social sharing and inspiration.

Figure 3.9 Nameplate of Tree Planting

By translating virtual actions into visible ecological results, this mechanism enhances user motivation, strengthens environmental identity, and transforms the app into a platform that connects individuals, communities, and nature.

3.3. Gamification Design

This section applies the Octalysis Framework proposed by Yu-kai Chou [7] to analyze the gamification strategy of the application. By integrating the framework's eight core drives, the design aims to activate users' motivation, promote sustained engagement, and transform daily low-carbon behaviors into emotionally meaningful and contextually relevant experiences.

3.3.1 Epic Meaning & Calling

Epic Meaning & Calling refers to the user's perception that their actions serve a purpose greater than personal gain, thereby triggering deeper motivation and engagement.

In this application, major themes—global warming, climate change, carbon emission—are introduced as the narrative background. Each low-carbon behavior did by the user, such as walking instead of driving, saving electricity, or reducing single-use plastics, is framed not merely as an individual choice but as a meaningful contribution to the planet. This narrative elevates everyday eco-actions into a form of mission, fostering a sense of purpose and value resonance at the cognitive level. Tree planting is used as both a symbolic and functional core element. Users collect point through completing tasks and use it to grow a virtual tree. Once fully matured, the tree can be planted in the real world and marked with a nameplate. The real tree serves not only as a symbol but as a tangible carrier of carbon absorption and ecological restoration. This integration of virtual actions with real-world environmental outcomes allows users to concretely connect their behaviors with earth health, enhancing both emotional attachment and perceived impact. This app also promotes a sense of collective mission. Users can join team-based challenges to complete low-carbon tasks together. This shared honor shifts the sense of mission from an individual level to a group level, reinforcing the idea that users are not acting alone but are part of a broader community working toward the same environmental goals.

3.3.2 Development & Accomplishment

Development & Accomplishment is the internal drive of making progress, developing skills, and eventually overcoming challenges, which leads to psychological satisfaction and a sense of achievement.

This application constructs a clear feedback loop: task completion, point accumulation, and visible progress, where every action directly contributes to a sense of development. By completing daily low-carbon tasks such as walking, saving electricity, or waste sorting, users earn points, which serves as the driver of their virtual tree's growth. This linkage reinforces the immediacy and visibility of be-

havior outcomes. As point accumulates, users can observe their virtual tree evolve through stages—from seed to sapling, small tree, and eventually a full-grown tree. Each stage features a visual transformation, supported by animated feedback to strengthen users' emotional engagement and sense of accomplishment. Crucially, when a user successfully nurtures a tree to maturity and meets the required conditions, the virtual achievement is translated into a real-world outcome. Users receive a digital certificate for their contribution, own a tree planted in the real world and marked with a nameplate, extending their sense of accomplishment beyond the screen and into the physical world. This integration of virtual rewards and real-world recognition not only deepens users' emotional identification with their achievements but also enhances long-term motivation by demonstrating tangible environmental impact.

3.3.3 Empowerment of Creativity & Feedback

Empowerment of Creativity & Feedback refers to the user's ability to make meaningful choices and receive timely, personalized feedback that reinforces their sense of self-expression.

This application gives users a creative autonomy, particularly in the development of their virtual tree. The growth path of the virtual tree is determined by accumulated point, allowing users to feel directly responsible for their tree's transformation. The guardian animal system also embodies this principle, enabling users to select from a range of animal companions with different appearances and personalities to reflect their preferences and values. In the real world, the application allows users to associate their contributions with a real tree planted in a community space. Unlike anonymous donations or background tree planting, this approach transforms users from passive participants into recognized contributors, enhancing their emotional investment. The app delivers feedback through animations, point increments, and real-time pop-ups after every completed task. For example, upon finishing a "Ride a bike instead of driving" task, the user might receive a celebratory animation: "Congratulations! You've got 12 points." This combination of visual and textual feedback strengthens the user's perception of achievement and reinforces the value of their actions, and encourages a deeper level of engagement and helps users internalize the link between action and impact.

3.3.4 Social Influence & Relatedness

This applications' social interaction function allows users to add others through invitation link. Users can visit each other's virtual tree to view tree growth progress, and if unclaimed point is present, collect it on behalf of their friends. Users can also leave messages. This "point stealing" mechanism enhances game-like interaction while maintaining a low-pressure, playful environment. A leaderboard is also integrated into the platform, ranking users based on their total point accumulation. This enables users to see their relative position, compare progress with friends, and receive motivational prompts. This type of light competition reinforces a sense of accomplishment and social presence. In team-based challenges, users can form teams to complete tasks together. For example, a weekly goal might involve reducing 100kg of CO_2 collectively. Each member's contribution is calculated toward the team's total, turning individual behavior into collaborative achievement and fostering a sense of shared purpose and teamwork. The guardian animal system also plays a supplementary social role. When users lack active social interactions, these characters provide emotional support by offering reminders, animated expressions, and dialogue. This ensures users feel connected and accompanied, even during solo use, and maintains emotional continuity across different interaction modes.

3.3.5 Scarcity & Impatience

Scarcity & Impatience refers to the psychological tendency of users to act promptly when faced with limited-time opportunities or resources. This sense of urgency can effectively drive user engagement and increase short-term activity.

To reinforce this mechanism, the app includes an "expiring point" reminder function. For example, the user may receive a prompt such as "Your points may be collected by others soon." These reminders leverage a fear of missing out (FOMO) [35] to subtly increase participation rates. The effect of these prompts is further amplified by animated reactions from the user's guardian animal. For instance, a concerned expression or a worried message from the guardian animal enhances the emotional pressure to act, transforming simple notifications into emotionally charged moments that reinforce engagement.

3.3.6 Unpredictability & Curiosity

Unpredictability & Curiosity refers to the user's intrinsic desire to explore the unknown, driven by the anticipation of surprise, variable rewards, and the discovery of new information. You want to find out what will happen next. If you don't know what's going to happen, your brain is engaged and you think about it often.

In the virtual tree growth system, each tree development and guardian animal are not fixed but depends on the user's selection. Interactions with guardian animals also incorporate elements of unpredictability. Task completions will trigger different emotional reactions, movements, or speech bubbles based on user context. These subtle variations foster a sense of realism in the companionship and deepen emotional connection to the system. Furthermore, users can use accumulated points to unlock different tree species and guardian animals. The randomness in visual outcomes and variety of available choices tap into users' curiosity and desire for personalization. This gamified exploration process encourages usage and strengthens long-term motivation through emotional discovery.

3.3.7 Loss & Avoidance

Loss & Avoidance highlights the tendency of users to be more motivated by the fear of losing something than by the prospect of gaining a similar reward. This psychological effect is a powerful driver for behavioral consistency.

In this application, the point got by completing tasks is available only for a limited time. For instance, points produced by a task expire within 48 hours if not claimed. If the user fails to log in and collect them in time, the point will be "taken" by other users. To reinforce this, the system triggers pop-up alerts from the guardian animal, such as "Your point is about to disappear—hurry and collect it!" These messages encourage users to revisit the app regularly and develop a habit of timely interaction. In the friend interaction system, unclaimed points can be collected by friends after a certain period. If this happens, users receive playful but noticeable system notifications such as "Your 20 points were collected by your friend momo." These notifications serve both as a gentle warning and a social stimulus, reinforcing the idea that failure to act results in visible loss.

3.3.8 Ownership & Possession

Ownership & Possession refers to the psychological drive that arises when users feel that something within the system belongs to them. This sense of ownership increases emotional attachment and motivates users to maintain, enhance, and protect their progress, especially when time, effort, or personal expression has been invested.

In this application, users' low-carbon behaviors are visualized as uniquely cultivated virtual trees. Each tree is tied to the user's individual progress. This design fosters a strong sense of personal ownership—users do not merely receive rewards from the platform; they actively grow something that reflects their efforts. Additionally, users can use points to unlock guardian animals. These characters will provide feedback, reminders, and celebration animations. If users remain inactive for an extended period, the animal may display sadness or confusion. This anthropomorphized feedback creates a sense of emotional responsibility, increasing the user's commitment to regular engagement.

This application also transforms virtual achievements into real-world outcomes. Once a tree reaches full maturity, it can be planted in community with a nameplate bearing the user's name. This physical realization of virtual contributions strengthens the perception of environmental impact and converts digital activity into something tangible, visible, and socially shareable.

3.4. Other Design

To enhance communication and emotional connection with users, this study also designed visual materials such as promotional posters and nameplates, supporting the application's core functions.

The promotional posters are used to raise awareness of global warming and attract user participation. The left poster features mascot characters delivering the message: "The Earth needs your help against global warming!" The right poster highlights the slogan "Sprout your green lifestyle, make Earth smile," with a cheerful Earth mascot holding a sprout. Both posters include a QR code to download the app.

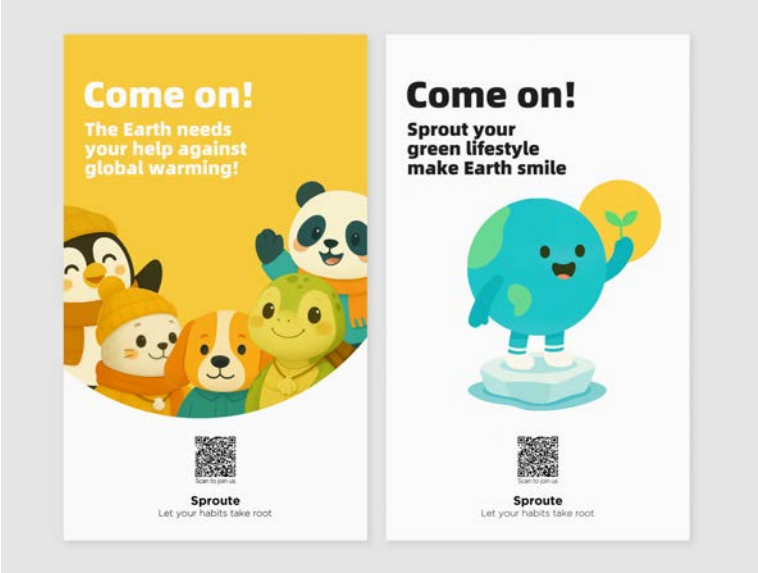


Figure 3.10 Poster Design

The tree nameplates, are designed to be placed next to real trees planted. Each nameplate includes placeholders for tree species, the planting user, date, and a unique serial number. The back of nameplate also feature a smiling green earth mascot and a QR code that links back to the application, enabling others to view their low-carbon journey and tree growth process. These nameplates act as tangible proof of contribution and a bridge between virtual action and real-world environmental impact.

Figure 3.11 Nameplate Design

Figure 3.12 Nameplate

Chapter 4
Design Validation

To ensure that the application design proposed in Chapter 3 effectively meets its intended goals—namely fostering long-term low-carbon behaviors through gamification, emotional engagement, and real-world feedback—this chapter adopts a structured validation strategy. Each evaluation method corresponds to a specific design objective, enabling a comprehensive assessment of functional usability, motivational effectiveness, and behavioral outcomes.

The validation consists of five components: a preliminary Kano Analysis to understand user expectations; a mid-term workshop to gather feedback on interface and emotional design; an Octalysis-based evaluation to assess motivational impact; a one-week behavior observation to examine real-world usage and habit formation; and a post-workshop survey to measure user perceptions and sustained engagement.

This mapping ensures that the key design principles—functionality, emotional connection, intrinsic motivation, and real-life impact—are systematically examined in the sections that follow.

4.1. Preliminary Study

4.1.1 Purpose

In the early stage of the design process, a preliminary study was conducted using the Kano Model to evaluate user expectations toward core functions of the proposed low-carbon lifestyle application. Originally developed by Japanese professor Noriaki Kano in the 1980s, the Kano Model classifies product features into five categories—Must-be, One-dimensional, Attractive, Indifferent, and Re-

verse—based on how users perceive their presence or absence [36].

By applying this model, the study aimed to identify which application functions are considered essential by users, which can significantly enhance satisfaction, and which are less relevant to the user experience. The results provide evidence for prioritizing design elements and refining the product road map.

4.1.2 Method

An online questionnaire was conducted based on the dual-question technique of the Kano Model, where each function is evaluated through two questions: how the user feels if the feature exists, and how the user feels if it does not exist. For each question, users chose from five response options: "I like it," "I think this feature is fine," "I don't mind either way," "I could accept it but would feel a bit dissatisfied," and "I dislike it."

The questionnaire covered five core functions. For the full version of the questionnaire, please refer to Appendix C.

Table 4.1 Functions evaluated in Kano analysis

Number	**Function Description**
F1	Task and Point Progress
F2	Cyber Tree Cultivation
F3	Real-World Tree
F4	Friend Interaction and Point Collection
F5	Community Ranking and Achievement Unlocking

4.1.3 Result Analysis

A total of 12 valid responses were collected. Based on the responses, functions were categorized into Kano types by analyzing users' emotional reactions toward the presence or absence of each feature. The classification results are summarized as follows.

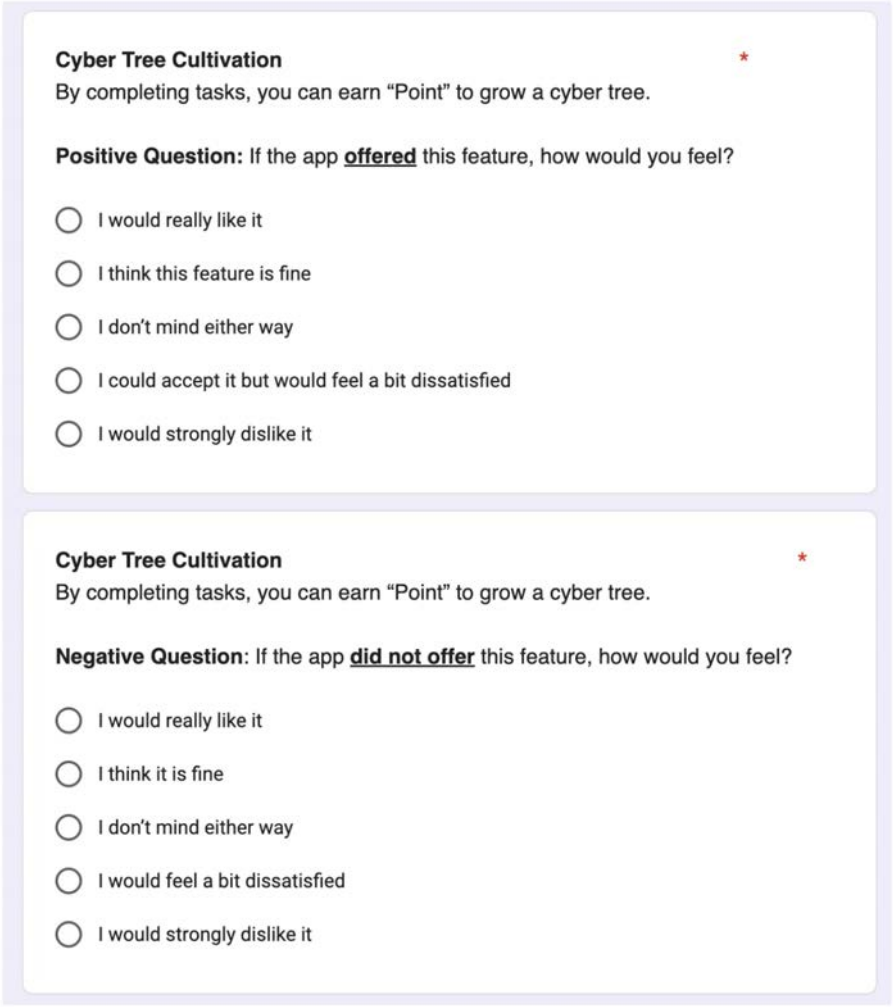


Figure 4.1 Questionnaire of F2

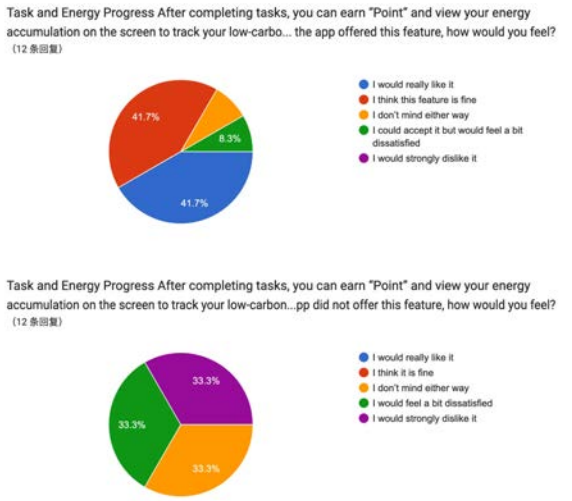


Figure 4.2 Feedback of F1

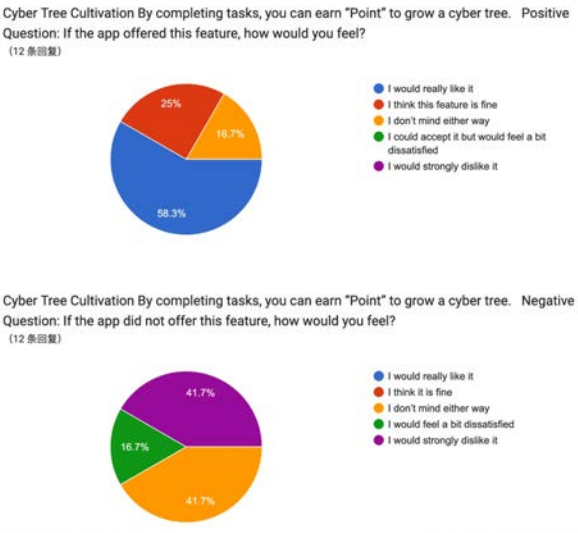


Figure 4.3 Feedback of F2

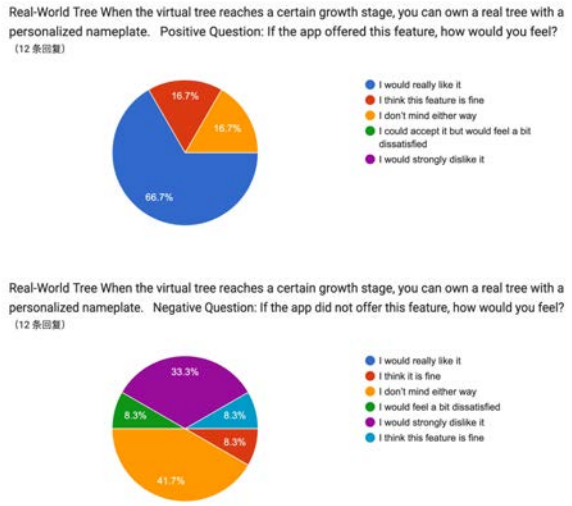


Figure 4.4 Feedback of F3

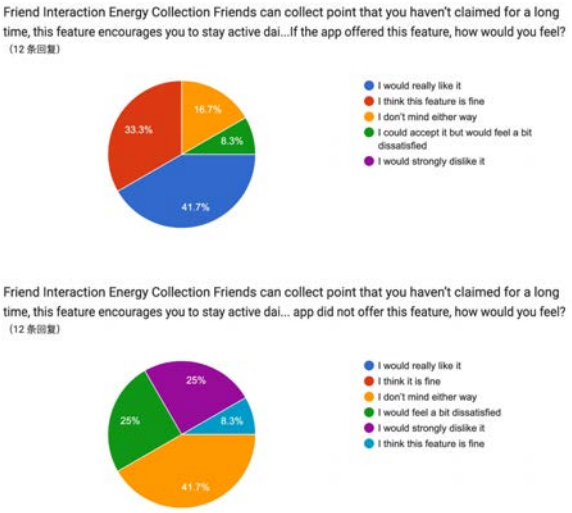


Figure 4.5 Feedback of F4

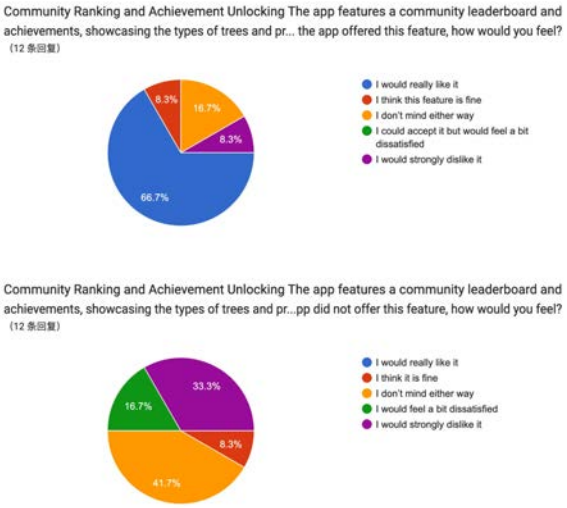


Figure 4.6 Feedback of F5

Table 4.2 Kano Classification Results

Number	**Function Description**	**Kano Classification**
F1	Task and Point Progress	Must-be
F2	Cyber Tree Cultivation	One-dimensional
F3	Real-World Tree	Attractive
F4	Friend Interaction and Point Collection	One-dimensional
F5	Community Ranking and Achievement Unlocking	Attractive

The results show that F1 was regarded as a Must-be function—indicating a basic expectation. F2 and F4 were categorized as One-dimensional funcitons, meaning their quality directly impacts user satisfaction. F3 and F5 were considered Attractive functions, which are not expected by default but create delight when implemented. This classification provides a clear hierarchy for feature prioritization during further development.

4.2. Mid-term Workshop

4.2.1 Purpose

To evaluate the usability and emotional resonance of the proposed application during the mid-stage of development, a user testing workshop was conducted on March 22, 2025, during a spring event hosted by Pulou Property in Hengxi, Ningbo. This event included a tree-planting activity, aligning naturally with the theme of the low-carbon application.

Figure 4.7 Event organized by Puluo Property

Figure 4.8 Tree I planted in event

The goals of the workshop were to verify whether the prototype aligns with users' low-carbon lifestyle habits, collect feedback on functions such as daily low carbon task, virtual tree growth, animal companion, and real world tree planting, and then identify potential usability issues and gather suggestions for future design.

4.2.2 Method

Eight residents were invited to use my prototype. I introduced the core concept and functions of the application and guided participants to use my prototype through Figama.

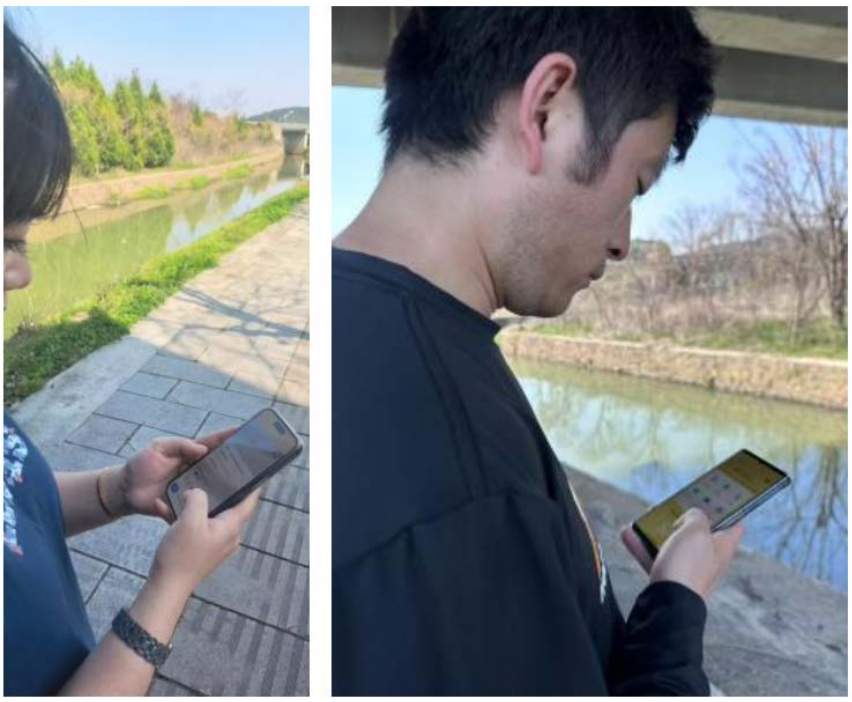


Figure 4.9 Partial scenes from the user testing

After the hands-on experience, participants completed a structured questionnaire consisting of:(A) Functional Experience and (B) Emotional Feedback. Section A used a 5-point Likert scale to evaluate satisfaction with the application's core features, including Interactive Questionnaire, Daily Low-Carbon Task, Virtual Tree Growth, Social Interaction, Guardian Animal Companion, Impact Visualization, and Real-World Tree Planting. Section B assessed the emotional responses of the participants, including their perceived sense of environmental achievement, emotional connection with virtual characteristics, motivation from social competition, willingness to engage in long-term low-carbon behavior and desire for personalization when planting a real tree. The results help to assess both the functional effectiveness and the emotional impact of the gamified design of the app.

环保应用用户体验问卷调查

A 功能体验

请在 1–5 分之间为以下功能模块打分（1 = 非常不满意，5 = 非常满意）：

功能模块	1	2	3	4	5
A1. 交互式问卷（任务开始前引导用户了解碳足迹）	□	□	□	□	□
A2. 每日低碳任务（例如步行、节能等）	□	□	□	□	□
A3. 虚拟树成长系统（完成任务促进树木成长）	□	□	□	□	□
A4. 社交功能与排行榜（与好友互动、偷能量等）	□	□	□	□	□
A5. 守护动物机制（角色陪伴与任务鼓励）	□	□	□	□	□
A6. 环保行为成效可视化（节碳统计、行为反馈）	□	□	□	□	□
A7. 现实植树联动（积分兑换种树、命名铭牌）	□	□	□	□	□

B 情感反馈

1. 您在使用过程中感受到的“环保成就感”程度如何？
□ 完全没有 □ 一般 □ 非常强烈

2. 守护动物是否增强了您对环保任务的亲近感？
□ 是 □ 一般 □ 没有

3. 排行榜是否激励您更积极参与低碳任务？
□ 非常激励 □ 一般 □ 无影响

4. 您是否愿意长期使用此应用记录低碳行为？
□ 非常愿意 □ 可能愿意 □ 不确定 □ 不愿意

5. 如果可以种一棵现实中的树，您是否希望它带有自己的名字和记录？
□ 非常希望 □ 可以考虑 □ 无所谓 □ 不需要

Figure 4.10 Workshop's questionnaire

4.2.3 Result Analysis

Participants rated seven functions as follows:

Table 4.3 Workshop satisfaction scores for seven major functions

Participant	**A1: Interactive Questionnaire**	**A2: Daily Low-Carbon Task**	**A3: Virtual Tree Growth**	**A4: Social Interaction**	**A5: Animal Companion**	**A6: Impact Visualization**	**A7: Real-World Tree Planting**
User 1	4	4	5	4	3	4	4
User 2	5	5	5	4	4	5	5
User 3	4	4	4	3	3	4	4
User 4	5	5	5	5	4	4	5
User 5	4	5	5	4	3	4	5
User 6	3	4	4	4	3	3	4
User 7	4	5	5	4	4	4	5
User 8	3	3	4	3	3	3	4
Average	**4.00**	**4.38**	**4.63**	**3.88**	**3.38**	**3.88**	**4.50**

Representative quotes from participants:

> User 1: "I love watching the tree grow every day after completing small tasks. It feels like taking care of a living thing, much more engaging than point-based apps I've used before."
>
> User 3: "The guardian animal looks cute, but it doesn't really do much. I'd like it more if it moved or spoke to remind me to do tasks."
>
> User 7: "I really like the real-world planting idea. Just like this event, knowing that I can see a tree I planted grow over time feels meaningful."

This workshop results affirm the app's positive reception in terms of emotional design and behavioral motivation. Particularly, the integration of symbolic tree growth, daily task, and real-world linkage proved highly resonant with users. However, enhancements in character interactivity and navigation clarity were identified as areas for improvement in the next iteration, social interaction and impact visualization also need to be optimized as well.

4.3. Octalysis Framework

4.3.1 Purpose

In user-centered application design, understanding and activating users' behavioral motivations has become one of the key factors for product success. Functional guidance alone is often insufficient to achieve long-term behavioral change. This section aims to evaluate the systematicity and effectiveness of gamified motivational strategies in this application, and to analyze how gamification can be used to motivate users to adopt and maintain low-carbon behaviors. The objectives of this framework are to assess the effectiveness of gamification elements, examine the sustainability and balance of motivation, and identify weak points in the motivation structure.

Through this, the study not only validates the gamified strategy of the application but also provides theoretical grounding and practical verification for its behavioral guidance effectiveness.

4.3.2 Method

This study adopts Yu-kai Chou's Octalysis Tool to systematically analyze the core functions of the application in terms of user motivation [7]. The framework identifies eight core motivational drives: Epic Meaning & Calling, Development & Accomplishment, Empowerment of Creativity & Feedback, Ownership & Possession, Social Influence & Relatedness, Scarcity & Impatience, Unpredictability & Curiosity, and Loss & Avoidance. Each driver was rated on a scale from 1 to 10 based on the participant's subjective experience, and participants were encouraged to write feedback on each core drives. These eight drives can be further classified along the dimensions of intrinsic vs. extrinsic motivation and rational vs. emotional drives, enabling a comprehensive understanding of the psychological mechanisms behind user engagement.

Source: `https://www.yukaichou.com/octalysis-tool/`

Figure 4.11 Octalysis Tool

To ensure that the Octalysis Framework is both representative and practically applicable, this study collected feedback from 30 participants of diverse ages and backgrounds. A combination of offline and online test was conducted to enhance the diversity of the sample and the credibility of the results.

In the offline test, participants were invited to experience the application in person. Under guided operation and observation, they experienced core functions such as daily low-carbon task, virtual tree growth, animal companion interaction, and the leaderboard. During the process, I conducted face-to-face discussions and subsequently assisted participants in completing the octalysis tool to rate the extent to which each core drive was activated, along with collecting qualitative feedback for each core drives.

Figure 4.12 Offline User Test

In the online test, I used screen sharing via conferencing software to introduce the application's core functions and interaction flow step by step. Some participants used Yu-kai Chou's Octalysis tool independently, while others provided verbal feedback, which was recorded by me to assess subjective ratings across the eight motivational drives.

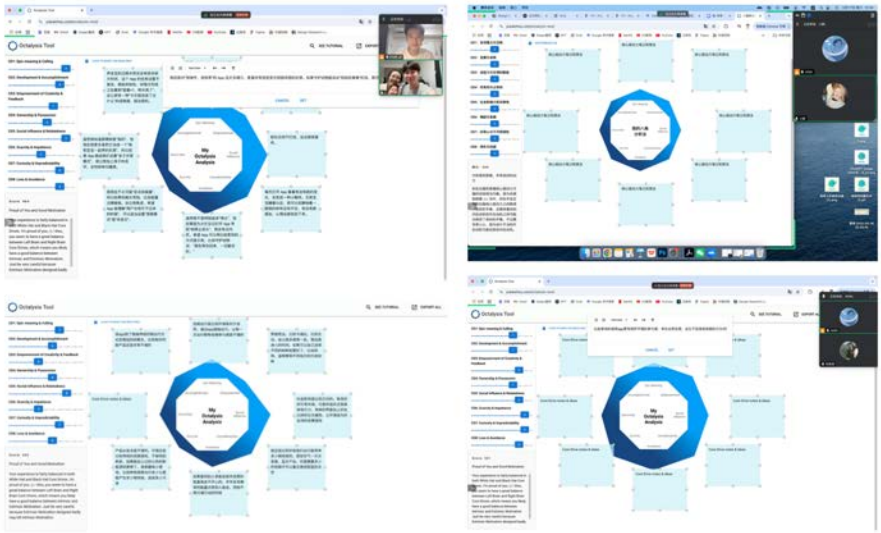


Figure 4.13 Online User Test

4.3.3 Result Analysis

This section presents the information of the participants and their evaluations of the application's core drives using the Octalysis Framework. The data collected covers a diverse group of users aged between 20 and 40, with various occupational backgrounds. Participants joined the workshop in two formats: online and offline. Those who attended offline (marked with ✓ in Table 4.4) participated in a face-to-face session, while online participants engaged remotely via digital surveys.

Table 4.4: Participant informations from the workshop

No.	**User**	**Gender**	**Age**	**Occupation**	**Offline**
1	Wang	Male	35	Postgraduate Student	✓
2	Cao	Male	26	Medical Sales Representative	
3	Wang	Female	26	Postgraduate Student	

No.	User	Gender	Age	Occupation	Offline
4	Liu	Female	20	Undergraduate Student	✓
5	Yang	Female	20	Undergraduate Student	✓
6	Zhou	Female	20	Undergraduate Student	✓
7	Yang	Male	20	Undergraduate Student	✓
8	Du	Female	20	Undergraduate Student	✓
9	Ying	Male	25	Bank Employee	
10	Lin	Female	32	Government Employee	✓
11	Dong	Female	38	Plastic Factory Owner	✓
12	Shen	Female	36	Medical Company Manager	✓
13	Fen	Female	31	Company Employee	✓
14	Luo	Female	29	Starbucks Employee	✓
15	Xi	Male	26	UI Designer	
16	Jia	Female	23	Undergraduate Student	
17	Cao	Male	26	Scene Designer	
18	Xu	Female	31	Postgraduate Student	✓
19	Yang	Female	23	Postgraduate Student	
20	Zhang	Female	26	Postgraduate Student	
21	Liu	Female	26	Postgraduate Student	
22	Ying	Male	28	High School Teacher	
23	Chen	Female	27	Kindergarten Teacher	

No.	User	Gender	Age	Occupation	Offline
24	Zhang	Male	26	UX Designer	
25	Zhu	Male	26	Postgraduate Student	
26	Tian	Male	27	Graphic Designer	
27	Xiong	Female	21	Undergraduate Student	✓
28	Sun	Male	30	Policeman	
29	Che	Male	24	Photographer	
30	Wang	Female	21	Undergraduate Student	

Participants were asked to rate the eight core drives (CD1–CD8) after experiencing the application. These drives correspond to the Octalysis Framework proposed by Yu-kai Chou [7], including CD1–Epic Meaning & Calling, CD2–Development & Accomplishment, CD3–Empowerment of Creativity & Feedback, CD4–Ownership & Possession, CD5–Social Influence & Relatedness, CD6–Scarcity & Impatience, CD7–Unpredictability & Curiosity, and CD8–Loss & Avoidance.

Table 4.5: User scores on core drives in Octalysis Tool

No.	User	CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8
1	Wang	8	8	8	7	9	6	9	7
2	Cao	7	9	6	7	8	6	8	9
3	Wang	9	8	7	6	9	5	8	8
4	Liu	8	9	8	7	9	9	8	7
5	Yang	8	7	6	6	9	5	9	7
6	Zhou	9	8	5	6	9	6	8	7

No.	**User**	**CD1**	**CD2**	**CD3**	**CD4**	**CD5**	**CD6**	**CD7**	**CD8**
7	Yang	8	7	6	6	9	5	8	6
8	Du	8	7	6	5	8	4	7	5
9	Ying	7	6	4	6	8	4	7	6
10	Lin	6	6	5	4	8	6	4	6
11	Dong	9	9	6	6	7	6	7	7
12	Shen	9	7	5	7	8	6	7	8
13	Fen	5	6	6	7	5	5	6	7
14	Luo	10	8	7	8	6	4	8	7
15	Xi	9	8	9	7	8	6	9	9
16	Jia	7	7	8	7	8	9	9	8
17	Cao	10	8	9	9	8	8	7	7
18	Xu	8	10	9	6	6	7	8	4
19	Yang	10	8	6	9	8	7	5	6
20	Zhang	8	8	8	7	8	5	8	5
21	Liu	8	4	6	5	5	7	3	8
22	Ying	7	5	6	7	6	4	7	7
23	Chen	10	9	7	6	8	4	6	8
24	Zhang	8	8	5	8	8	6	6	9
25	Zhu	7	7	6	8	5	6	8	5
26	Tian	9	6	5	6	6	6	5	7

No.	User	CD1	CD2	CD3	CD4	CD5	CD6	CD7	CD8
27	Xiong	7	6	6	8	9	6	8	8
28	Sun	8	7	6	8	9	5	7	8
29	Che	8	8	7	6	7	6	8	6
30	Wang	9	8	6	9	8	7	8	9
	Average	8.13	7.4	6.47	6.8	7.63	5.87	7.2	7.03

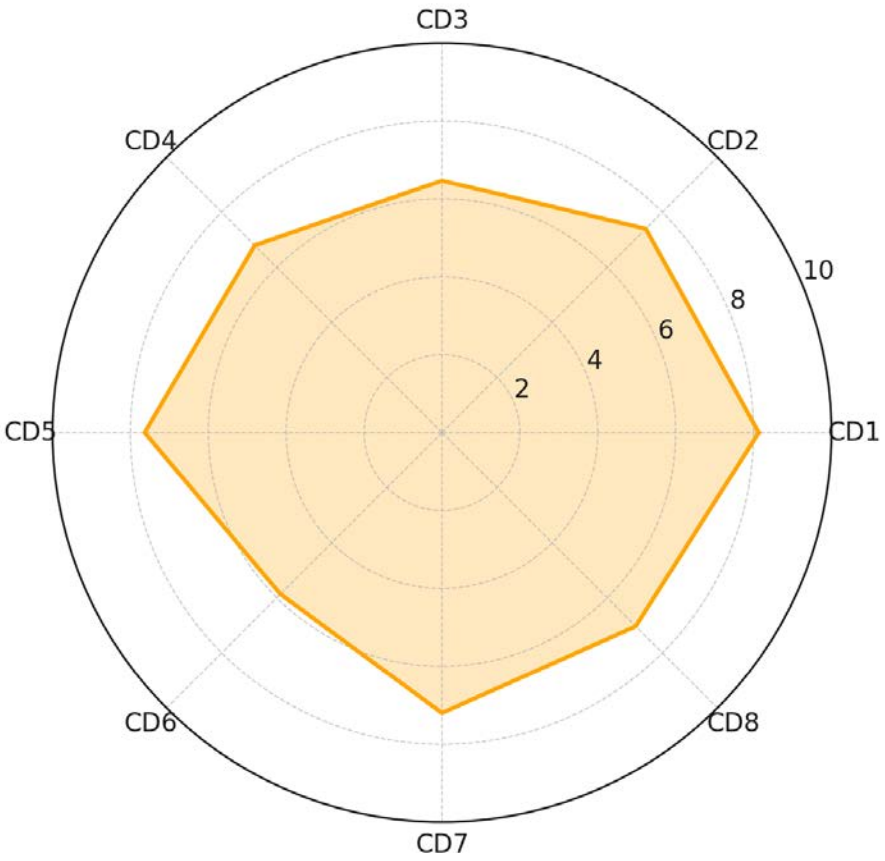


Figure 4.14 Radar chart of core drives

Table 4.5 and Figure 4.14 show the average scores across the eight core drives

based on the feedback from 30 participants. The results indicate that CD1 (Epic Meaning & Calling) received the highest average score of 8.13, suggesting that users were highly motivated by the sense of purpose and contribution conveyed by the application. CD5 (Social Influence & Relatedness) also performed well, with a mean score of 7.63, highlighting the effectiveness of the app's social and peer interaction features, such as friend comparisons and the leaderboard system.

In contrast, CD6 (Scarcity & Impatience) recorded the lowest average score of 5.87, indicating that scarcity-based mechanisms like limited-time rewards or urgency triggers were perceived as less engaging or insufficiently implemented. CD3 (Empowerment of Creativity) and CD4 (Ownership & Possession) received moderate scores (6.47 and 6.80, respectively), suggesting room for improvement in features related to personalization, feedback, and user control.

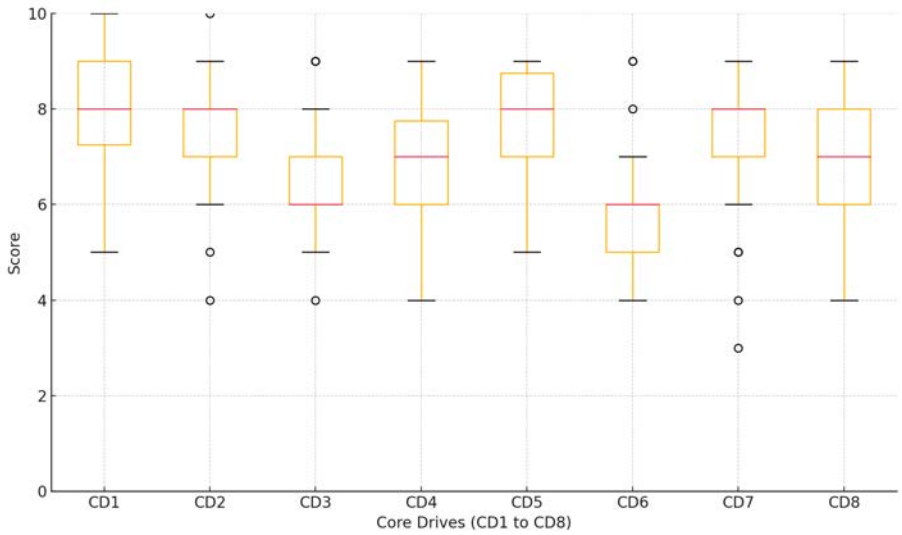


Figure 4.15 Box plot of core drives

Figure 4.15 presents the distribution of user scores for each of the eight core drives using a box plot. Shows that CD1 (Epic Meaning) and CD5 (Social Influence) consistently received high ratings from most users. These two dimensions also exhibit relatively narrow interquartile ranges, indicating a high level of agreement among participants regarding their motivational effectiveness. In contrast, CD6 (Scarcity) shows a wider distribution with several low outliers, reflecting

divergent user perceptions toward scarcity-based mechanics. Similarly, CD3 (Empowerment) and CD7 (Unpredictability) also show moderate variation, suggesting these mechanics were effective for some users but less engaging for others.

In addition to score ratings, participants also provided feedback on eight core drives. These open responses offered valuable insights into how users perceived and interpreted different motivational elements beyond scores. For example:

User 2 commented on CD1 (Epic Meaning & Calling):

> *"This app conveys a sense of environmental mission. The idea of planting real trees doesn't emotionally excite me in a hype-driven way, but it does make me feel that this initiative is meaningful and worthwhile."*

Figure 4.16 Comments from User 2

User 1 commented on CD2 (Development & Accomplishment):

> *"Good way to motivate users. If there are some pics showing the bad effects of bad behavior might work better. Such as displaying the destroyed forests if people pay little attention to CO_2."*

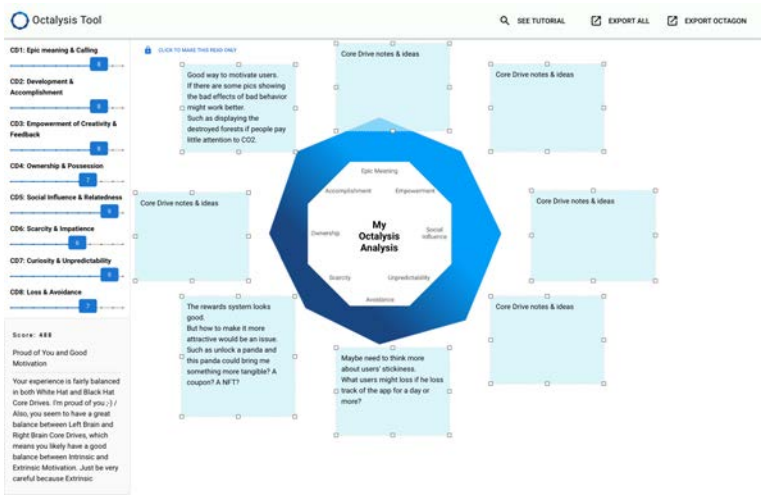


Figure 4.17 Comments from User 1

User 22 commented on CD3 (Empowerment of Creativity & Feedback):

> *"The current guardian animals and virtual tree feedback are very cute and have guiding value, but I hope to add "knowledge feedback" or "environmental tips" so that it will be more convincing when encouraging students to participate."*

Figure 4.18 Comments from User 22

User 10 commented on CD4 (Ownership & Possession):

"Currently, the trees all look quite similar, which feels a bit monotonous. If users could decorate their own forests or choose a style, it would enhance their sense of participation."

Figure 4.19 Comments from User 10

User 14 commented on CD5 (Social Influence & Relatedness):

"What I like most is being able to visit my friends' forests to steal energy, leave messages, and see their guardian animals. Planting trees together with friends feels even more interactive than liking posts on social media."

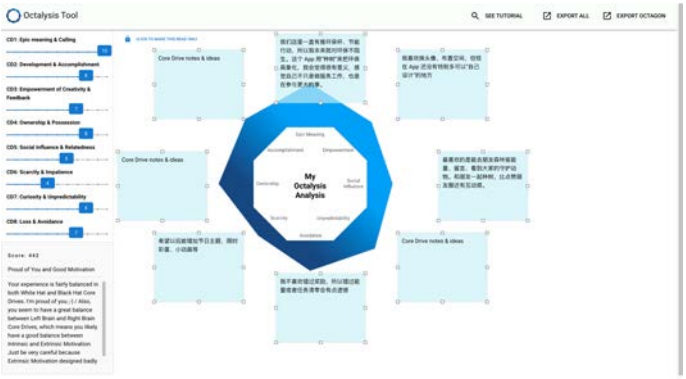


Figure 4.20 Comments from User 14

User 15 commented on CD6 (Scarcity & Impatience):

> *"The limited-time point collection mechanism doesn't stress me out—it's more of a gentle reminder. Since my work schedule is irregular, I suggest adding an "point storage cap" or a "slow protection mode" to make the experience more accommodating for users with different routines."*

Figure 4.21 Comments from User 15

User 3 commented on CD7 (Unpredictability & Curiosity):

> *"Every day I open the app to check for any new changes—it has become a small source of anticipation. Especially after my baby falls asleep, I can quietly take a look at whether my tree has bloomed or if I have any new friends, and it really helps calm my mood."*

Figure 4.22 Comments from User 3

User 27 commented on CD8 (Loss & Avoidance):

> *"If I don't open the app for a few days, I feel a bit uneasy—especially when I see that my tree hasn't grown or a friend leaves a message like "Come back and collect your energy," I'll quickly open it. But the pressure isn't too much—it's just right, a kind of "soft nudge."*

Figure 4.23 Comments from User 27

These reflections complement the quantitative results and highlight areas where

motivational design can be further refined. A complete collection of user feedback for all eight core drives is available in Appendix D.

In summary, the analysis of user ratings reveals that the application effectively leverages intrinsic motivational factors, particularly Epic Meaning & Calling (CD1) and Social Influence & Relatedness (CD5), which received high average scores of 8.13 and 7.63, respectively, with low variance, indicating strong emotional and relational resonance with users. Development & Accomplishment (CD2) and Loss & Avoidance (CD8) also performed well, with average scores of 7.4 and 7.03, respectively, suggesting that task progression and mechanisms to prevent progress loss (e.g., notifications about uncollected points) successfully motivate users. However, Empowerment of Creativity & Feedback (CD3) and Ownership & Possession (CD4) received moderate scores of 6.47 and 6.80, respectively, indicating that features like personalization and feedback could be enhanced to strengthen user engagement. Similarly, Scarcity & Impatience (CD6) and Unpredictability & Curiosity (CD7) scored lower, with averages of 5.87 and 7.2, respectively, and showed greater variance, suggesting that extrinsic motivators such as limited-time tasks and surprise elements require more thoughtful integration to avoid disengagement or confusion.

The combination of quantitative results, visualized through radar and box plots, and qualitative user feedback provides valuable insights into how different gamification strategies are perceived. These findings serve as an empirical basis for iterative design refinement, ensuring future updates to the application better align with diverse user expectations and maximize sustained engagement.

4.4. Behavior Change Observation

4.4.1 Purpose

To examine whether the gamified elements embedded in the application effectively led to actual behavior change, this section introduces a short-term observational analysis based on self-reported user data collected before and after a trial period of app usage. The aim was to assess not only changes in specific behaviors but also shifts in users' environmental awareness and decision-making tendencies.

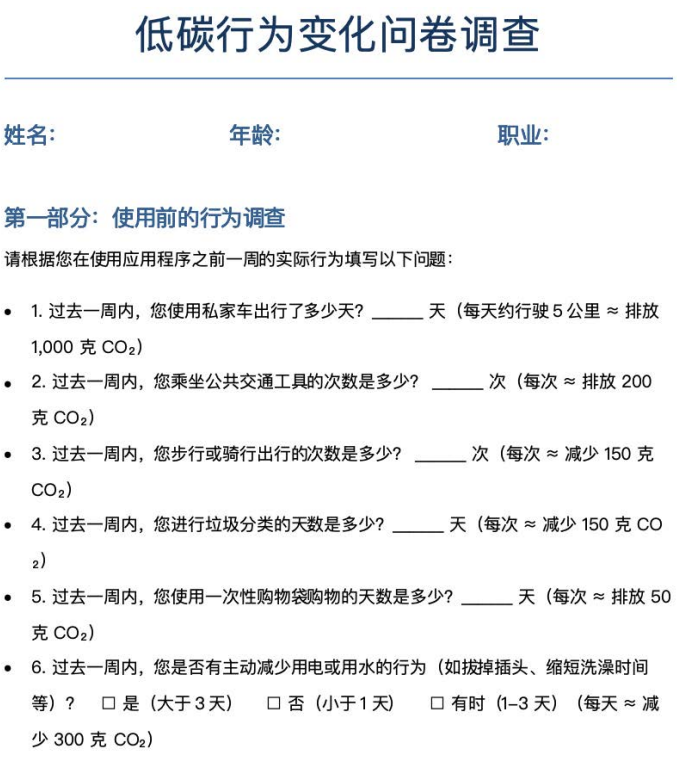
4.4.2 Survey Design

Part 1: Usage Behavior Assessment

Participants were asked to recall and report the frequency of specific low-carbon behaviors they performed during the week prior to using the application. These behaviors included:

- Number of days using a private car (each day of 5 km driving ≈ 1,000 g CO_2)
- Number of times using public transportation (≈ 200 g CO_2 per trip)
- Number of walking or cycling trips (≈ 0 g CO_2)
- Number of days practicing waste separation (≈ 150 g CO_2 reduction per time)
- Number of days using disposable plastic bags while shopping (≈ 50 g CO_2 per time)
- Frequency of active energy/water-saving behaviors (≈ 300 g CO_2 reduction per day)

These reference values were provided in the questionnaire and also displayed within the app to help participants better understand the environmental impact of each behavior.



低碳行为变化问卷调查

姓名: 年龄: 职业:

第一部分：使用前的行为调查

请根据您在使用应用程序之前一周的实际行为填写以下问题：

- 1. 过去一周内，您使用私家车出行了多少天？ _____ 天（每天约行驶 5 公里 ≈ 排放 1,000 克 CO_2）
- 2. 过去一周内，您乘坐公共交通工具的次数是多少？ _____ 次（每次 ≈ 排放 200 克 CO_2）
- 3. 过去一周内，您步行或骑行出行的次数是多少？ _____ 次（每次 ≈ 减少 150 克 CO_2）
- 4. 过去一周内，您进行垃圾分类的天数是多少？ _____ 天（每次 ≈ 减少 150 克 CO_2）
- 5. 过去一周内，您使用一次性购物袋购物的天数是多少？ _____ 天（每次 ≈ 排放 50 克 CO_2）
- 6. 过去一周内，您是否有主动减少用电或用水的行为（如拔掉插头、缩短洗澡时间等）？ ☐ 是（大于 3 天） ☐ 否（小于 1 天） ☐ 有时（1–3 天）（每天 ≈ 减少 300 克 CO_2）

Figure 4.24 Behavior Assessment

Part 2: Daily Behavior Log During App Usage

Throughout the 7-day trial period of the app, I conducted daily checks with each participant to record their behaviors based on a predefined table with consistent categories. This approach enabled the capture of real-time changes following their exposure to the app's feedback mechanisms. Participants responded to whether they had performed each target behavior, allowing for analysis and cumulative comparison.

第二部分：App 使用期间的每日记录（共 7 天）

请记录您在使用应用程序后了解对应行为的碳排放量后的 7 天期间内的每日行为：

日期	是否使用私家车	是否乘坐公共交通	是否步行或骑行出行	是否垃圾分类	是否使用一次性购物袋	是否主动节水节电
7.11						
7.12						
7.13						
7.14						
7.15						
7.16						
7.17						

Figure 4.25 Daily Behavior Log

4.4.3 Comparative Results

The data collected from 8 participants over a 7-day trial using sproute application revealed distinct shifts in behavior frequency and environmental awareness.

According to corrected pre- and post-trial data, only one participant (Cao 26) showed a reduction in private car usage, cutting down from 5 to 4 days by substituting walking or omitting unnecessary trips. Two participants (Lin 32 and Wang 26) showed slight increases (from 6 to 7 days and 5 to 7 days, respectively), indicating car dependency or routine constraints. The remaining five participants either maintained zero car usage or showed no change. Overall, private car behavior proved resistant to change in the short term, reflecting strong lifestyle habits.

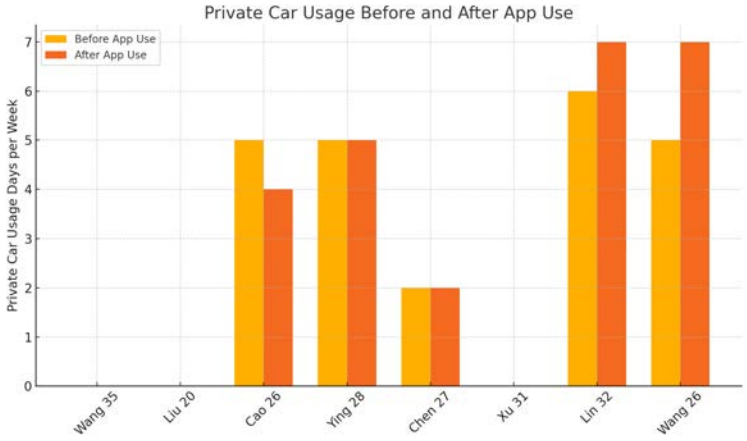


Figure 4.26 Private car usage

Public transportation usage showed minimal change across the participants. Liu and Wang (35), who had moderate usage levels before the trial (5 and 3 times, respectively), maintained the same frequency after using the app. Xu slightly increased usage from 2 to 3 times, while the rest of the participants—including Ying, Lin, Cao, Chen, and Wang (26)—remained at zero usage both before and after the intervention.

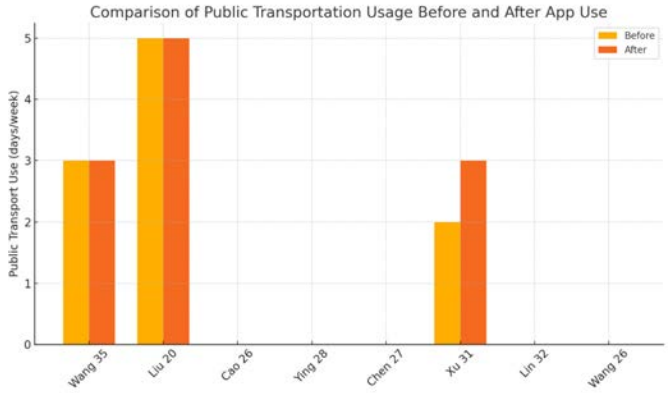


Figure 4.27 Public transportation usage

Walking and cycling behaviors showed consistent improvement across the par-

ticipants. For instance, Liu increased from 5 to 7 days, Chen from 2 to 4, Cao from 1 to 2, and Lin from 0 to 3. Ying and Wang (26) also started engaging in walking, rising from 0 to 2 and 0 to 1 respectively.

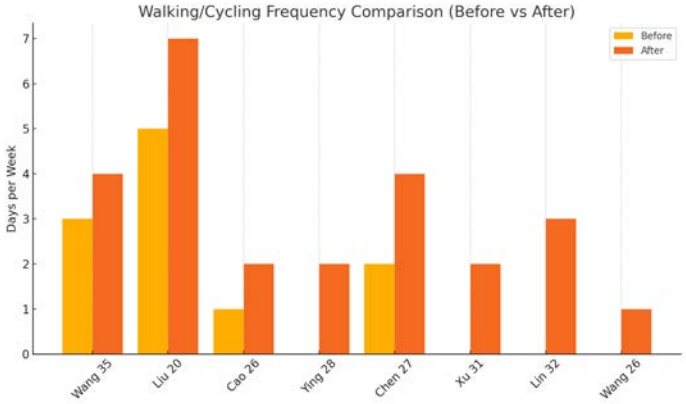


Figure 4.28 Walking and cycling behaviors

The comparison of waste separation behavior before and after using the application indicates a notable improvement among most participants. Based on the weekly data, participants such as Wang (35) and Xu (31) already exhibited high engagement (6–7 days per week) prior to the trial and maintained their performance. In contrast, participants with little to no prior practice—such as Liu (20), Cao (26), Ying (28), Chen (27), Lin (32), and Wang (26)—showed increases ranging from 2 to 5 additional days of sorting behavior over the 7-day period. On average, the waste separation frequency rose from 1.5 to 4.5 days per week across the group.

Figure 4.29 Waste separation

The use of disposable plastic bags generally decreased across participants during the 7-day trial. Wang (35) reduced usage from 3 to 2 days, Liu from 5 to 2, and Ying from 4 to 2. Xu and Lin showed the most notable progress, dropping from 2 to 0 and 6 to 5 respectively. While the change for some was modest, overall frequency of plastic bag use declined, suggesting improved environmental mindfulness.

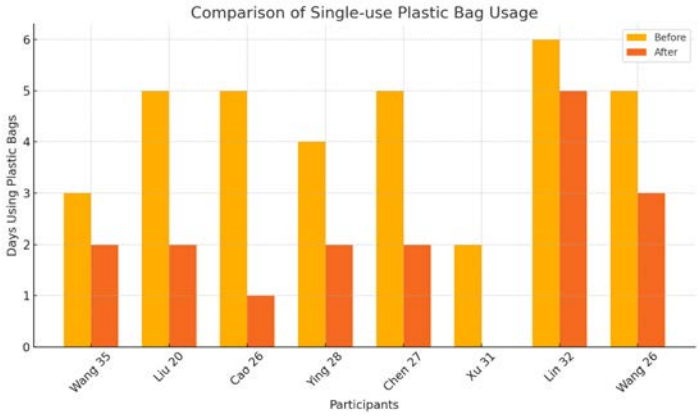


Figure 4.30 Plastic usage

In terms of energy-saving behaviors—such as unplugging devices or shortening shower time—the comparative data indicates a clear upward trend among partic-

ipants. For instance, those who reported occasional energy-saving behavior prior to the trial (e.g., Wang 35 and Xu) maintained or slightly increased the frequency of such actions. Meanwhile, participants who initially had little to no energy-saving habits (e.g., Liu, Ying, Chen, Lin, and Wang 26) demonstrated significant improvements, with increases ranging from 2 to 5 days.

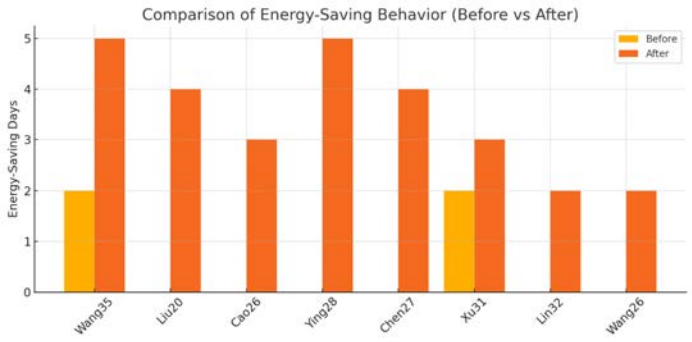


Figure 4.31 Energy saving

Overall, all six behavior categories exhibited some level of improvement, indicating that the gamified design effectively raised awareness and influenced both habitual and intentional eco-conscious behaviors. This multidimensional outcome supports the app's potential for fostering a broader cultural shift toward sustainability, even within a short intervention period. However, for behaviors that are planned or perceived as necessary—such as air travel or daily commuting—change remains more difficult to achieve within a gamified framework.

4.5. Post-Workshop Survey

To evaluate the impact of the gamified application, a post-workshop survey was conducted after the Behavior Change Observation workshop. 8 participants completed a reflective survey through an online follow-up meeting conducted after the workshop to assess whether their environmental awareness or behaviors had shifted after using the app. The questions focused on four core areas:

- Perceived motivational impact: After using the app, have you become more

aware of the environmental impact of your daily behaviors?

- Actual behavior adjustments: Has the app encouraged you to adopt new low-carbon behaviors?
- Influence of gamification elements: Do you think the gamification mechanisms in the app have a motivating effect on your actions?
- Willingness to maintain low-carbon practices: Are you willing to continue in the future?

This timing and method allowed direct and immediate feedback while participants' experiences were still fresh, allowing a meaningful estimate of the potential longer-term influence of the workshop.

4.5.1 Survey Results

The survey focused on four core areas: perceived motivational impact, actual behavioral adjustments, willingness to maintain low-carbon practices, and the influence of gamification elements on sustained engagement. The key findings are summarized below:

- **Perceived motivational impact:** 7 out of 8 participants reported an increased awareness of their environmental impact after using the app.
- **Actual behavior adjustments:** 6 participants stated that the app encouraged them to try new low-carbon behaviors they had not previously considered.
- **Influence of gamification elements:** 7 participants felt that gamified feedback mechanisms, such as energy points and tree growth visuals, positively influenced their motivation and sense of accomplishment.
- **Future Use Intention:** 6 participants expressed willingness to use applications in the future, while 2 answered "maybe," suggesting conditional interest depending on app quality and added functionality.

4.5.2 Considerations

The results of the post-workshop survey suggest that the app was effective in promoting environmental awareness and encouraging the change of manageable behaviors. Specifically, 7 out of 8 participants reported an increased awareness of their environmental impact, while 6 stated that the app motivated them to adopt new eco-friendly actions they had not previously considered. Although high-inertia behaviors such as commuting by private car remained largely unchanged due to practical or occupational constraints, participants still demonstrated a greater sense of environmental responsibility and expressed willingness to engage in low-carbon behaviors over the long term.

Gamification elements were cited by 7 participants as key motivational factors. These features contributed to a stronger sense of accomplishment and purpose, reinforcing continued engagement through intuitive and emotionally resonant feedback.

Overall, the survey results indicate that the app holds potential for promoting sustainable behavior change through emotionally engaging design and gamified feedback mechanisms.

4.6. Summary

A comprehensive evaluation was conducted to assess the effectiveness of the proposed low-carbon lifestyle application from both motivational and behavioral perspectives. This included an Octalysis-based user rating workshop with 30 participants, a 7-day behavioral observation involving 8 users, and a follow-up reflection survey to gather qualitative impressions.

The Octalysis-based analysis revealed that the application effectively leveraged intrinsic motivators, particularly Epic Meaning & Calling (CD1) and Social Influence & Relatedness (CD5). These strengths were linked to key design features introduced in Chapter 3, such as the symbolic tree-growth mechanic, the real-world planting system, and the use of guardian animals. Participants reported a strong emotional connection to the app's purpose and appreciated its ability to visualize their environmental contributions in both virtual and physical realms. Meanwhile, lower scores in Scarcity & Impatience (CD6) and Ownership & Posses-

sion (CD4) highlighted areas where urgency cues or further personalization could be enhanced.

The 7-day behavioral trial provided evidence of real-world impact. Several participants reported adopting new low-carbon actions—such as reducing plastic bag usage, increasing waste separation accuracy, and conserving household electricity. While high-inertia behaviors like car commuting remained difficult to change, the app succeeded in raising awareness and motivating small but sustainable shifts in daily routines.

Lastly, the post-workshop survey confirmed the app's perceived value. Most users reported increased environmental awareness, a motivation to explore low-carbon behaviors, and a willingness to sustain these practices beyond the trial. These findings support the app's core design hypothesis: that emotionally engaging, gamified systems grounded in real-world feedback can foster both motivation and meaningful behavioral change.

Chapter 5
Conclusion

5.1. Findings

This study explored how gamification can motivate people to engage in low-carbon behaviors. Based on user feedback, several insights emerged regarding the psychological mechanisms that drive sustainable engagement.

The Octalysis Framework revealed that Epic Meaning & Calling (CD1) and Social Influence & Relatedness (CD5) were the most positively perceived motivational elements. Participants reported strong emotional resonance with the application's environmental narrative, particularly the concept of nurturing a virtual tree that could lead to the planting of a real tree. The leaderboard, friend interaction, and visual feedback also contributed to a sense of community participation and healthy comparison. In contrast, Scarcity & Impatience (CD6) and Unpredictability & Curiosity (CD7) received lower average scores and displayed more variance among users. These results suggest that time-limited or surprise-based mechanics require more clarity or better integration to be perceived as meaningful. Overall, intrinsic motivations such as purpose and social connection proved more effective than extrinsic triggers such as urgency or randomness. The results also confirmed that visual metaphors, such as a growing tree or a guardian animal, can facilitate emotional engagement, ownership, and habit formation. The use of environmental storytelling, personalization, and social interaction helped to translate abstract carbon concepts into tangible daily behaviors.

Behavioral observations during the 7-day app trial provided further validation. The gamified design influenced routine, low-effort behaviors such as walking, waste separation, reducing plastic bag usage, and turning off unused lights. Participants showed measurable increases in these habits, highlighting the power of feedback loops, emotional rewards, and symbolic progress in shaping everyday actions.

However, the study also found that purpose-driven behaviors—such as commuting by private car or traveling by plane—remained largely unchanged. These behaviors are often tied to work obligations, lifestyle preferences, or convenience, and are less susceptible to gamified nudges within a short intervention period. This indicates that while gamification can effectively reshape flexible daily habits, deeper structural or contextual interventions may be necessary to address entrenched high-emission behaviors.

The post-workshop survey results further supported the app's overall effectiveness in fostering environmental awareness and behavioral change. Most participants reported increased consciousness about their carbon impact, with specific mentions of changes in manageable daily behaviors such as walking more, sorting waste, reducing plastic bag use, and conserving energy. In particular, 7 out of 8 participants felt more environmentally aware, and 6 stated they were motivated to adopt new low-carbon actions. Feedback mechanisms were cited as motivational factors that enhanced engagement. These findings affirm that gamified elements can positively influence user motivation and reinforce sustainable habits, especially when emotional and visual feedback are combined.

These findings directly address the two initial research questions. First, the application demonstrated that gamification can motivate users to adopt and maintain manageable daily behavior. By integrating narrative-driven design, task feedback loops, social interaction, and identity-based engagement, the system sustained users' participation and encouraged behavioral repetition. Second, the study showed that virtual rewards—when emotionally designed and visually meaningful—can be transformed into deeper emotional engagement and translated into real-world environmental actions. The "cyber tree to real tree" mechanism and nameplate system played key roles in converting digital achievements into a sense of environmental ownership and physical contribution.

5.2. Limitations

This study has several limitations. First, the sample size was limited to 30 participants, all within the age range of 20 to 40. Although participants were diverse in terms of occupation and background, the findings may not be generalizable to

broader demographic groups, particularly older adults or adolescents.

In addition, the behavioral observation period was limited to 7 days. While this short-term intervention provided initial insights into user engagement and behavior adjustment, it does not allow for a comprehensive evaluation of long-term behavioral change, sustained app usage, or actual reductions in carbon emissions over time.

5.3. Future Work

For future iterations, I will conduct a long-term deployment lasting one to three months to better evaluate whether the application can truly sustain low-carbon behaviors beyond just short-term motivation. During that period, track key metrics like user retention, task completion rates, and estimated reductions in carbon emissions. This would help provide solid evidence of long-term impact. I also think it is important to test the app with a more diverse range of users, such as families, schoolchildren, and older adults, to see how well it generalizes. Since China has a collectivist cultural background that values community and shared responsibility, adding team-based challenges or family-oriented tasks might really resonate with those user groups. Another key direction is improving the lower-scoring motivators in Section 4.3.3. For example, to strengthen Empowerment of Creativity & Feedback, I could add features such as customizable forest layouts or allow users to create their own eco-friendly challenges. As for Scarcity & Impatience, which had the lowest score of 5.87, I would consider adding things like dynamic countdowns for weekly eco-missions or surprise quizzes with rewards, like special guardian animal animations, to boost a sense of urgency and curiosity. These ideas also directly address the user feedback that I received about unclear mechanics or lack of excitement.

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Appendices

A. Detailed App Analysis

Table A.1 Analysis of Ant Forest (China)

Analysis Dimension	**Description**
Core Function	Record low-carbon behaviors, generate virtual energy, and redeem for real tree planting.
Tracking Method	Calculate carbon reduction based on user behaviors, but does not directly display total individual reduction.
Gamification Elements	Virtual energy, tree growth, leaderboards, social interaction.
Emotional Connection	Virtual tree growth, satellite map for viewing planting results, environmental education content.
Virtual Achievement	Energy accumulation, tree growth, leaderboard ranking.
Real Achievement	Real tree planting, support for ecological projects.
Advantages	Strong gamification design, large user base, significant social impact.
Notes	Integrated into Alipay, awarded the UN "Champions of the Earth" (2019).

Table A.2 Analysis of EXPO Green Challenge (Japan)

Analysis Dimension	**Description**
Core Function	Incentivizes eco-friendly actions through task-based challenges linked to Expo 2025.
Tracking Method	Activity recording: behaviors like bottle use, cleanup.
Gamification Elements	Points, lottery, event stamps, task badges.
Emotional Connection	Expo theme, national event, regional participation.
Virtual Achievement	Point
Real Achievement	Points redeemed for eco-goods (toothbrushes, rental coupons, etc.).
Advantages	Official support, clear real-world reward mechanism.
Notes	Theme-based, possibly limited post-event retention.

Table A.3 Analysis of Reduce CO_2 (Japan)

Analysis Dimension	**Description**
Core Function	Tracks daily carbon emissions and calculates reductions.
Low-carbon Tracking Method	Estimates CO_2 reduction based on user activity records.
Gamification Elements	No significant gamification features.
Emotional Connection	Raises awareness through environmental education content.
Virtual Achievement	No virtual rewards.
Real Achievement	No direct real-world feedback.
Advantages	Clear data visualization, intuitive cost savings, educational function.

Table A.4 Analysis of Green Carbon Club (Japan)

Analysis Dimension	**Description**
Core Function	Contribute to sustainability through eco-friendly actions; earn points to exchange green products.
Tracking Method	Based on user activity records.
Gamification Elements	Points, leaderboard, challenges.
Emotional Connection	Polar bear IP, community interaction.
Virtual Achievement	Points, leaderboard, challenge completion.
Real Achievement	Exchange eco-friendly products.
Advantages	Engaging gamification, strong social interaction, mascot enhances emotional connection.
Notes	Designed for Kawasaki residents and surrounding areas; users find the redemption process inconvenient.

Table A.5 Analysis of Commons (United States)

Analysis Dimension	**Description**
Core Function	Tracks and guides sustainable consumption.
Tracking Method	Calculates carbon footprint based on consumption data.
Gamification Elements	Points, badges, group challenges.
Emotional Connection	Community interaction, sustainable brand recommendations.
Virtual Achievement	Badges, reward exchange.
Real Achievement	Investment in carbon offset projects (e.g., MANOA REDD+).
Advantages	Great UI design, attractive rewards.
Notes	Instagram followers: 290k+.

Table A.6 Analysis of JouleBug (United States)

Analysis Dimension	**Description**
Core Function	Encourages and rewards sustainable habits for employees.
Tracking Method	Estimates savings of CO_2, water, and waste based on user activity and expert research.
Gamification Elements	Points, challenges, leaderboard, badges, trophies.
Emotional Connection	Community interaction.
Virtual Achievement	Badges, trophies, leaderboard competition.
Real Achievement	No direct real-world feedback.
Advantages	Diverse tasks, corporate customization support.
Notes	Users enjoy task variety but complain about lag and repetitive features.

Table A.7 Analysis of Klima (Germany)

Analysis Dimension	**Description**
Core Function	Carbon footprint calculation and offset subscription, funding science-backed reduction projects.
Tracking Method	Calculates carbon footprint based on lifestyle questions.
Gamification Elements	No significant gamification features.
Emotional Connection	Builds trust through real-time project tracking and transparent fund allocation.
Virtual Achievement	No virtual rewards.
Real Achievement	Funds climate projects (e.g., in Ghana); users can track project progress.
Advantages	Accurate carbon calculations, transparent projects.
Notes	Users find the interface visually appealing but want more project stories.

B. Sproute Link

The interactive prototype of the Sproute application is available at:

- **Figma Prototype:** https://www.figma.com/proto/...

C. Kano Questionnaire Link

The complete version of the questionnaire used in Section 4 is available online at:

- **Access link:** https://docs.google.com/forms/...

D. User Comments on Core Drives

A full list of user feedback, including annotated screenshots and comments related to each of the eight Octalysis core drives, can be accessed online:

- **Access link:** https://www.notion.so/User-Comments-...