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Sustainable Entrepreneurship Project

**Gamifying Sustainability: Evaluating the Effectiveness and Ethical
Implications of Gamified Pro-Environmental Behavior through
User Reviews of the EarthHero App**

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Abstract

This thesis explores how gamification can effectively and ethically promote pro-environmental behavior (PEB). A qualitative case study analyzed 425 user reviews of EarthHero, a non-commercial mobile app that supports climate action through personalized behavior change. The study employed a hybrid thematic approach, combining inductive coding with two theoretical frameworks: the Octalysis Framework based on Chou (2019) for motivation and the Seven Problem Domains identified by Nyström (2021) for ethical evaluation. Findings show that goal setting, challenges, and progress tracking are perceived as the most motivating features, aligning with intrinsic motivators such as autonomy and accomplishment. Users valued these features more than extrinsic rewards like points or badges. Ethical concerns from the users were minimal and the app was largely perceived as transparent and respectful. However, some critiques highlighted issues of data accuracy and contextual accessibility. The study concludes that ethical, autonomy-supportive design enhances engagement and calls for future research in sustainability gamification ethics to incorporate inclusivity and contextual fit.

Key Words: Gamification, Pro-environmental Behavior, Sustainability, Octalysis Framework, Seven Problem Domains, Behavior change, Motivational design, App reviews

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1. INTRODUCTION

Gamification can be a powerful tool for promoting pro-environmental behavior (PEB). By integrating game-like elements into sustainability-focused apps, it becomes possible to motivate individuals to adopt more sustainable lifestyles (Douglas & Brauer, 2021). This thesis explores how users perceive the effectiveness and ethical implications of such gamified systems, using the *EarthHero* app as a case study.

In the face of the escalating climate crisis, it has become clear that addressing climate change demands more than policy interventions and technological innovation. It necessitates widespread adoption of PEB (Dioba et al., 2024), defined as "behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world" (Kollmuss & Agyeman, 2002, p. 240). Yet individuals often face psychological, social, and structural barriers, such as limited agency and systemic inequities (Gifford, 2011). A persistent gap remains between awareness and action - known as the 'value-action gap' - as seen in struggles to adopt sustainable diets despite recognizing their benefits (Essiz et al., 2023; Fink et al., 2021; Venghaus et al., 2022).

Gamification uses game-like elements to increase engagement in non-game contexts (Deterding et al., 2011). It has the potential to motivate individuals to adopt sustainable behaviors, and its application is increasingly being explored in the context of environmental protection (Douglas & Brauer, 2021; Miao et al., 2022; Ouariachi et al., 2020). Linked to behavioral economics, it has expanded across domains including health, education, and business, where it can improve motivation by balancing extrinsic and intrinsic incentives (Hammady & Arnab, 2022; Haque et al., 2024; Manzano-León et al., 2021). Consequently, gamification has found widespread interest in industry as well as academia with research outputs steadily increasing (Nyström, 2021) and is increasingly being recognized as an effective tool for encouraging sustainable behaviors (Miao et al., 2022). Studies have commonly identified points, badges, and leaderboards as some of the most frequently used gamification elements (Abdul Rahman et al., 2018; Hallifax et al., 2023; Khaldi et al., 2023). Sailer et al. (2017) demonstrate that distinct gamification elements, including badges, leaderboards, and narrative components, contribute in varying ways to the satisfaction of core psychological needs, namely competence, autonomy, and relatedness, which in turn shape user motivation. Another study examined gamification in the context of PEB and found that elements like rewards, feedback, competition, and goal setting were most frequently used and linked to

behavioral theories such as Self-Determination Theory and the Octalysis Framework (Miao et al., 2022). The Octalysis Framework developed by Chou (2019) will serve as one of the theoretical frameworks in this study and is described in detail in Section 2.1.

While gamification offers innovative pathways for fostering PEBs, it also introduces ethical complexities. Research highlights concerns about power dynamics, manipulation, and transparency, which can undermine user autonomy and well-being (Klock et al., 2023). As Marczewski (2017) notes, gamification itself is not unethical, its ethical implications depend on the designer's intentions. Like any tool, gamification can be used constructively or exploitatively, and it is the designer's responsibility to use it ethically (Marczewski, 2017). These issues often arise when business objectives overshadow individual welfare, inadvertently creating systems that prioritize engagement at the expense of user empowerment (Kim & Werbach, 2016). Its inherent connection to ethics arises from its primary objective of shaping human actions, making the designer's intentions and respect for user autonomy and dignity critical in determining whether the system promotes positive change or veers into manipulation (Rozalén, 2024). For example, some gamified systems rely on hidden incentives or exploitative design elements that may coerce users into behaviors they would not consciously choose. Nyström (2021) identified seven problem domains (7PD) relevant to the ethical evaluation of gamification. As the second framework underpinning this study's ethical analysis, the 7PD will be explained in more detail in Section 2.2

Ethical concerns surrounding gamification design remain underexplored, especially as technological advancement continues to outpace the development of ethical guidelines (Beck et al., 2019; Boncu et al., 2022; Kim & Werbach, 2016). While some studies have examined the influence of gamified features on user engagement and satisfaction, for example, in mobile health applications, research into user perceptions of these elements and their ethical implications is still emerging. App reviews, as a form of user-generated data, offer valuable insights into how gamification is experienced across diverse audiences. They can help surface perceived barriers to engagement and ethical concerns that might otherwise go unnoticed in traditional research approaches (Schmidt-Kraepelin et al., 2019).

To explore how gamification can promote PEB while maintaining ethical integrity, this study examines reviews of *EarthHero* - a non-commercial mobile application designed to support climate action through personalized behavior change (EarthHero, n.d.-b). *EarthHero* guides users

in reducing their carbon footprint by suggesting concrete actions across domains like food, energy, and transport. The app incorporates various gamification elements such as challenges, goal setting, and progress tracking to encourage sustainable practices. Its strong alignment with both motivational design and ethical principles makes it a suitable case for examining user perceptions through the lens of effectiveness and ethics.

Addressing current research gaps requires focusing on both gamification's effectiveness and ethical design. This study examines which elements users find effective and how they assess their ethical implications. It also assesses the usefulness of two theoretical frameworks (see Chapter 2) for analyzing user perceptions and guiding future research in gamification and sustainability. Beyond framework evaluation, the study offers insights into how users articulate ethical and motivational experiences, showing how user-generated data can inform theory in persuasive technology and sustainable design. While user feedback often emphasizes functionality over ethics, this research aims to uncover relevant ethical insights in an underexplored area. The findings also aim to inform the ethical and practical design of future gamified systems by providing actionable recommendations for designers, sustainability advocates, and policymakers.

The central research question is: *What gamification elements are perceived as effective in promoting pro-environmental behavior, and how do users evaluate their ethical implications?*

The structure of this research is as follows: First, the next section introduces the two theoretical frameworks that form the basis for the deductive phase of the coding. Second, the methodology for data collection and analysis is described in detail. The results are then presented, organized according to the two main dimensions of the study. This is followed by a discussion of the findings in relation to existing literature and their alignment with the theoretical frameworks. Limitations of the research and practical as well as theoretical implications are discussed. Finally, the study concludes with an answer to the research question and suggestions for future research.

2. THEORETICAL FRAMEWORKS

This research will be based on two complementary approaches, ensuring that the investigation can balance the two perspectives. This dual approach aims to produce multifaceted results, allowing both ethical and efficiency considerations to be assessed.

2.1 The Octalysis Framework (Chou, 2019)

The first theoretical framework applied in this research is the *Octalysis Framework*. Developed by Yu-Kai Chou, it is a gamification design model that categorizes gamification elements into eight core drives of motivation: Epic Meaning and Calling, Development and Accomplishment, Empowerment of Creativity and Feedback, Ownership and Possession, Social Influence and Relatedness, Scarcity and Impatience, Unpredictability and Curiosity, and Loss and Avoidance (Chou, 2019).

Epic Meaning and Calling motivates individuals by connecting their actions to a greater purpose or cause that drives them to act beyond personal gain.

Development & Accomplishment engages users through challenges and rewards and creates a reinforcing cycle of engagement as their achievements are recognized.

Empowerment of Creativity and Feedback encourages users to explore, innovate, and shape their experience, with feedback guiding their creativity and learning.

Ownership and Possession cultivates user engagement through a sense of ownership, whether it's virtual goods or accomplishments, enhancing their sense of control and personal achievement.

Social Influence and Relatedness is influenced by social interactions, including fitting in, competing, or cooperating with others, fostering a sense of connection and community.

Scarcity & Impatience taps into urgency and the fear of missing out, pushing users to act quickly.

Unpredictability & Curiosity sustains interest through novelty and uncertainty and keeps users engaged through new experiences.

Loss & Avoidance reinforces commitment by emphasizing the cost of inaction, often driving continued engagement and persistence.

The drives are grouped as *white hat* (positive) motivators, which support positive emotions and long-term engagement, and *black hat* (urgent) motivators, which create urgency but may reduce user comfort. They can also be understood as aligning with either intrinsic or extrinsic motivation, helping to explain the appeal and impact of different gamification elements (Chou, 2019). Thus, the framework is well-suited for analyzing the effectiveness of gamification elements as it provides a taxonomy (Weber et al., 2022) and has previously been applied in evaluations of gamified systems aimed at promoting PEB (Miao et al., 2022; Ouariachi et al., 2020). Therefore, it aligns with the goal of this research: understanding how users perceive gamification features, especially in promoting PEB.

Previous research using the Octalysis Framework has shown that white hat drives such as *Epic Meaning and Calling* and *Ownership and Possession* are consistently integrated into successful gamification platforms promoting PEB. Furthermore, platforms that balanced white hat and black hat motivators, as well as intrinsic and extrinsic motivators, showed higher engagement potential. Specifically, platforms that integrated multiple core drives and balanced motivational elements scored highest, suggesting that diverse, well-rounded designs enhance user engagement and behavior change (Ouariachi et al., 2020).

2.2 The Seven Problem Domains (7PD) (Nyström, 2021)

Additionally, this research will use the 7PD identified by Nyström (2021). They were derived through a literature review on negative side effects in gamification and will be used as a guiding tool to assess the ethical implications of gamification elements in apps promoting PEB. While there are existing frameworks that address specific ethical concerns, such as user autonomy, the field of ethical research in gamification for mobile apps remains underexplored. As such, the *7PD* provide a useful structure to help identify ethical concerns from a broad perspective. This exploratory approach makes it possible to uncover ethical issues that may not yet be fully explored in existing research. Although the 7PD are not a formal framework, they provide a holistic view of various ethical concerns, presenting a more nuanced understanding of the potential consequences of gamification in this domain. These domains are interconnected and collectively offer a comprehensive approach to evaluating the ethical dimensions of gamification in this research (Nyström, 2021).

The 7PD identified by Nyström (2021) are: Motivation, Addiction, Competition and Collaboration, Manipulation, Data Integrity, Surveillance and Privacy and Ethics and Exploitation.

The first domain, *Motivation*, highlights how extrinsic rewards can undermine intrinsic motivation by shifting users' focus on incentives rather than the task itself, often leading to disengagement once rewards are removed. *Addiction* refers to the risk of compulsive use, as gamified systems might entice users to engage beyond healthy limits. *Competition and Collaboration* examines how overly competitive elements can harm teamwork and detract from shared goals. *Manipulation* involves covert influences that steer users toward actions they might not otherwise choose, particularly when game mechanics exploit psychological triggers. *Data Integrity* addresses ethical risks associated with collecting and repurposing user data without informed consent. *Surveillance and Privacy* reflect concerns over constant tracking, with users feeling monitored or exposed when personal information is shared without clear boundaries. Finally, *Ethics and Exploitation* encompasses instances where gamification extracts effort or value from users without fair compensation or consideration, especially in contexts like labor or education.

2.3 Application of Theoretical Frameworks

This study applies the Octalysis Framework and the 7PD not only as theoretical foundations but also as analytical tools to guide the deductive phase of the thematic analysis. While the Octalysis Framework is used to interpret how gamified features align with user motivation, the 7PD are employed to identify and categorize ethical concerns expressed in user reviews. Specifically, the Octalysis Framework supports the coding of motivational drives to help clarify which elements of the app design contribute most to sustained engagement. The 7PD, in turn, provide a lens to examine potential ethical risks, including manipulation or fairness in design.

These frameworks are applied during the deductive coding phase described in Section 3.4, following an initial round of inductive coding. This hybrid approach enables a structured yet flexible analysis, combining theory-driven insights with data-grounded themes.

By linking conceptual models directly to user-generated feedback, the study not only evaluates the effectiveness and ethics of gamification but also assesses the practical value of these frameworks for future research on sustainability-oriented persuasive technologies.

3. METHODS

This study focuses on user perceptions of a mobile application designed to support PEB, using a qualitative case study approach. Publicly available user reviews serve as the primary data source, offering insight into how users experience, evaluate, and respond to gamification features within apps supporting PEB.

App store reviews provide direct, user-generated reflections on perceived usability, effectiveness, and ethical concerns, making them a valuable alternative to traditional data collection methods such as interviews or surveys (e.g., Dąbrowski et al., 2022; Jha & Mahmoud, 2019). Given their accessibility and volume, app reviews are particularly well-suited to analyzing user perspectives on digital behavior-change tools (Hedegaard & Simonsen, 2013; McIlroy et al., 2016).

To explore these user perspectives in depth, this research adopts a qualitative case study design. Case studies are well-suited to examining complex, real-world phenomena within specific contexts, allowing for a rich, contextualized understanding of user experiences (Yin, 2018). For app-based sustainability interventions, a case study enables focused analysis of how users engage with design features intended to influence behavior (Baxter & Jack, 2008). Rather than attempting broad generalizations across many apps, this approach allows for a detailed thematic investigation of one app that exemplifies the use of gamification to promote PEB.

3.1 App Selection

A multi-step process was used to identify a suitable app for analysis (see Figure A1). An initial pool of 115 apps was compiled through app store keyword searches and curated blog recommendations. This mixed approach aligns with best practices in similar app review research (Funnell et al., 2022; Tan et al., 2020), ensuring relevant and conceptually rich apps are not excluded due to platform filtering or visibility issues. After screening for relevance to individual PEB, presence of gamification features, and a minimum of 10,000 installs, in line with Tan et al. (2020), four apps remained. *EarthHero* was selected as the final case due to its cross-platform availability, high review volume, and strong alignment with the study's focus.

3.2 Data Collection

User-generated reviews were collected from the Google Play Store and Apple App Store using Python-based web scraping tools. The scraping process was carried out using google-play-scraper and app-store-scraper, and the extracted reviews were transformed into structured formats (CSV) for further analysis. The full scripts are provided in Appendix B. Each entry included review text, star rating, date, and platform metadata. This automated process enabled efficient and reproducible data collection from publicly available sources (Khder, 2021).

While app reviews offer valuable, user-generated insights into real-world app usage, they are subject to key methodological limitations (Panagiotidi, 2024). These include self-selection bias (users choose whether and when to review), a tendency toward extreme sentiment (very positive or negative), limited contextual detail, and platform filtering mechanisms (e.g., Apple's pre-moderation). To mitigate these issues, reviews were collected in bulk from two distinct app stores and subjected to strict inclusion criteria. Only reviews that provided substantive commentary on gamification features, user experience, or ethical considerations were retained. Reviews that were extremely short (< 5 words), focused only on technical issues, or were unrelated to the study's objectives were excluded (see Funnell et al., 2022). This structured cleaning helps strengthen the analytical quality of the dataset. However, the findings should still be interpreted as subjective user perceptions, not general truths.

The cleaning process was then implemented in multiple steps, including the manual removal of duplicate entries, corrupted or unreadable content, and reviews unrelated to user experience or gamification. This rigorous cleaning reduced the dataset to 425 high-quality reviews appropriate for thematic analysis. This approach aligns with prior app-based research (Funnell et al., 2022; Tan et al., 2020), which similarly filtered large reviews to retain only content-rich, thematically relevant user feedback.

All reviews were collected from the U.S. App Stores, as the scraping tools used for data extraction exhibited regional limitations, and the U.S. store consistently yielded the highest volume of relevant user feedback. Including only U.S.-based reviews also ensured linguistic consistency and simplified the analysis. While this introduces a limitation in terms of geographic diversity, the dataset provides sufficient thematic saturation and reflects a significant share of the app's total user base.

3.3 App Description

EarthHero is a free, non-commercial mobile application designed to support individual and collective climate action through behavior change. It offers users personalized action plans grounded in scientific research, addressing key domains such as food consumption, travel, energy use, and civic engagement (EarthHero, n.d.-a). Users can browse various categories (e.g., Travel and Transport) and choose from more than 100 detailed actions. Each action is rated and contributes to the user's progress by awarding "EarthPoints" (see Figure A2, for an example action interface) (EarthHero, n.d.-a). The app enables users to calculate their carbon footprint and track their emissions over time, presenting progress through visual feedback (see Figure A3). To enhance motivation, *EarthHero* incorporates several gamification elements, including goal setting, rewards, and progress tracking features. In addition, the app emphasizes community by connecting users to a global network of over 100,000 participants in more than 150 countries. The overarching aim is to help individuals take effective climate action in their daily lives by fostering both personal accountability and a sense of shared purpose (EarthHero, n.d.-b).

3.4 Data Analysis

The collected user reviews of *EarthHero* underwent thematic analysis, which is well-suited for exploring patterns in user perceptions of gamification elements and their ethical implications. It allows for a nuanced examination of recurring themes and topics within the reviews (Byrne, 2022). The study can provide insights into how different gamification features are experienced and evaluated by users. This approach has been effectively applied in similar app review studies (see Funnell et al., 2022).

The analysis followed Braun & Clarke (2006) six-phase method, starting with open coding and ending in theme development and interpretation. After familiarization with the data, the analysis began with inductive, open coding to identify emergent themes grounded in user feedback. These were then organized into higher-order thematic categories using Atlas.ti. In the second round, deductive codes were applied based on the Octalysis Framework, to interpret how gamified features shaped user motivation. Ethical dimensions were explored through the 7PD. The rationale and process for applying these frameworks are explained in more detail in Chapter 2.3. However,

this proved difficult: while some ethical concerns were present, they rarely aligned neatly with the categories defined in the 7PD.

This resulted in four inductive and two deductive themes with the inductive themes encompassing a total of 19 codes and sub-codes. The inductive themes and their corresponding codes, including sub-codes, are presented in Table C1. The deductive themes and their codes are based on the Octalysis Framework (Chou, 2019) and the 7PD by Nyström (2021), as outlined in Chapter 2. Detailed descriptions and illustrative examples for each of the employed deductive codes can be found in Table C2 and Table C3, respectively.

Analytic memos were created throughout the process to track emerging patterns and guide the theme development. Individual reviews were often assigned multiple codes, as users frequently addressed several aspects of the app within a single comment.

Lastly, to identify how specific gamification elements in *EarthHero* align with motivational mechanisms, a co-occurrence analysis was conducted between coded gamified features and the Core Drives of the Octalysis Framework. The results of this analysis are presented in Table C4. This technique allows for the exploration of relationships between thematic categories, providing deeper insights into how users experience and interpret design features in context (Guest et al., 2011).

3.5 Ethical considerations

This study complied with institutional ethical standards and did not involve direct human participation. All data consisted of publicly available user reviews from app stores, collected via automated tools in accordance with platform terms of use. Reviews were anonymized by removing any identifiable information (e.g., usernames), and only content relevant to the research aims was retained. The data was stored securely in accordance with GDPR regulations and University guidelines. No personal data was shared or processed beyond initial collection, and users' privacy and anonymity were fully respected.

4. RESULTS

Reflecting the dual focus of this question, the results are organized into two main sections: (1) Perceived Effectiveness of Gamified Elements and (2) Ethical Implications of Gamification Design.

Figure 1 below provides an overview of the frequency of all inductive codes, grouped by thematic category. To enhance clarity, only the subcodes are displayed for the more complex categories (*Actions*, *Perceived Impact*, *Accountability*, and *Gamified Elements*).
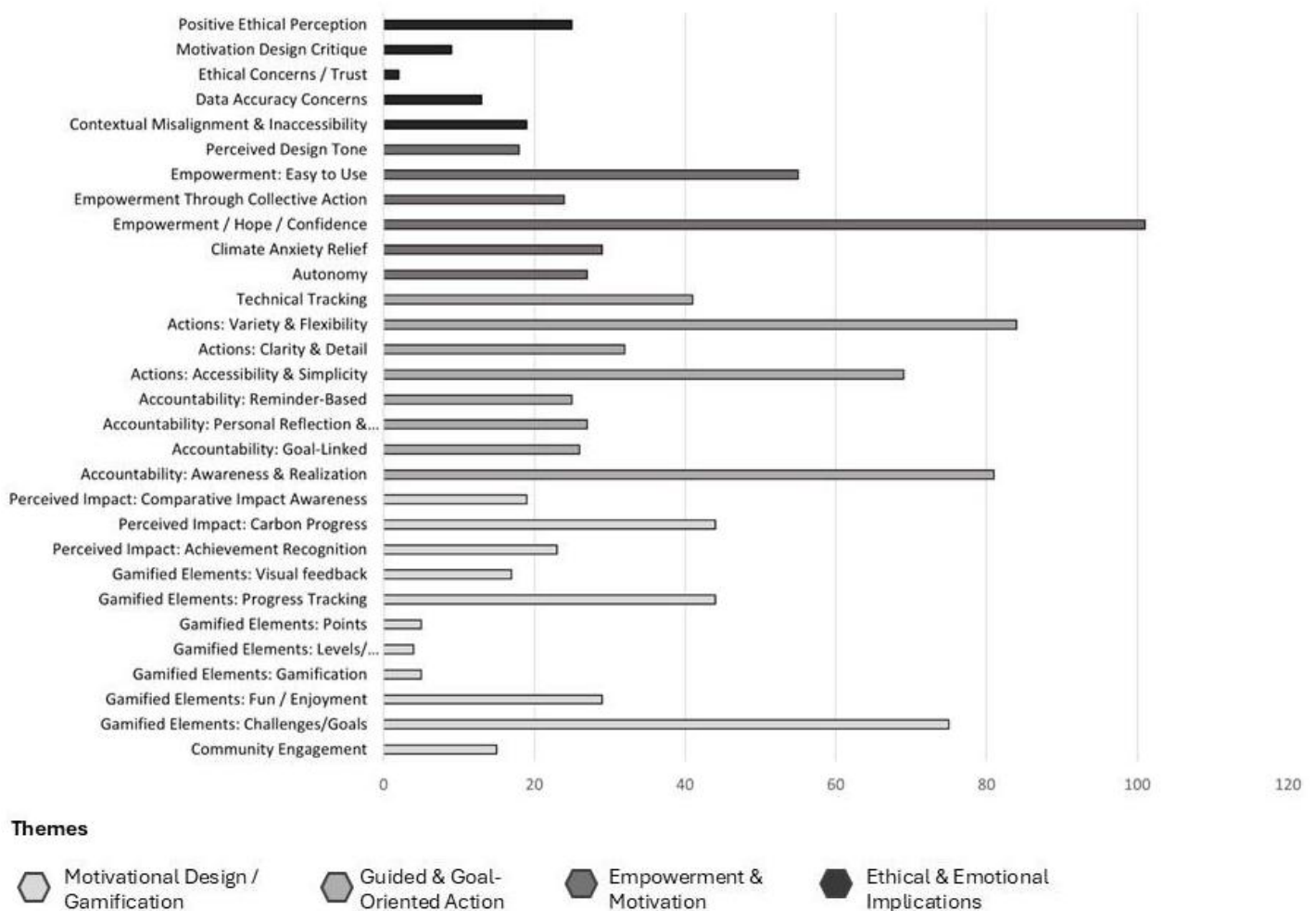

Figure 1: Frequency of Inductive Codes Grouped by Thematic Category

4.1 Perceived Effectiveness of Gamified Elements

This subsection presents the findings derived from user reviews that discuss how EarthHero's gamification elements are perceived in terms of their motivational impact.

To structure the findings from the inductive thematic analysis, three overarching themes were developed: (1) *Motivational Design & Gamification*, (2) *Guided & Goal-Oriented Action*, and (3) *Empowerment & Motivation*. As illustrated in Figure 1, the frequency of codes across these themes is relatively balanced, suggesting that user perceptions were distributed fairly evenly among different aspects of motivation and engagement.

4.1.1 Motivational Design & Gamification

This theme captures which elements of EarthHero's gamified design users found motivational, and how they contributed to engagement and sustained action. Three key codes were developed: *Community Engagement*, *Gamification Elements*, and *Perceived Impact*.

Community Engagement refers to users' appreciation of shared purpose and participation through the app. While the app does not center heavily on social features, a subset of users (n = 15) still described a sense of belonging or collective action:

"Putting in the actions that I already do, identifying actions to work on, and participating in the app community are all super fun." (G078).

Gamification Elements (n = 150) were explicitly mentioned in reviews highlighting game-like features such as goals, badges, points, and progress mechanics. Of these, *Challenges and Goals* (n = 75) were by far the most frequently mentioned and were often associated with motivation through structure and achievement:

"I've really enjoyed the 30-day challenge - it gave me a focus and made it fun to stay consistent." (G086).

Progress Tracking (n = 44) and *Visual Feedback* (n = 17) were additional motivators, especially for users who valued seeing their achievements accumulate:

"It allows you to put in information about your habits and then you can set an emissions reduction goal and works towards that by establishing habits suggested in the app. I find the way

it's set up very motivating since it shows you a graph of reductions you've made over time."

(G246).

While traditional features like *Points* and *Levels/Badges* were present, they were only rarely mentioned in the dataset (n = 5 and n = 4 respectively) which suggests that these features may be less noticeable or less valued by users in this context. However, several users explicitly described the app as fun, enjoyable, or uplifting. These instances were coded under Fun/Enjoyment (n = 29).

The code *Perceived Impact* (n = 81) reflects users' experiences of feeling that their actions within the app translated into meaningful environmental outcomes. It was particularly shaped by three recurring patterns. First, several users described a sense of *Achievement Recognition* (n = 23), noting that completing actions or reaching milestones gave them a feeling of accomplishment and personal success. These comments often highlighted the satisfaction of progressing through challenges or consistently meeting goals. Second, many users referred to *Carbon Progress* (n = 44), where visualizations and data tracking allowed them to observe reductions in their estimated emissions over time. This quantitative feedback appeared to enhance users' sense of agency, as they could see concrete evidence of improvement. Finally, *Comparative Impact Awareness* (n = 19) emerged in reviews where users mentioned comparisons between their own data and benchmarks. As one user noted,

"Graphs that compare your own output to the rest of the world help you understand where you personally are having the biggest effect." (G085).

Across these codes, users described the app as not only guiding action but also validating it, turning everyday behaviors into something visible, trackable, and socially or ecologically relevant. Overall, this theme reflects that users respond most positively to structured, goal-oriented design elements - especially those that allow them to visualize progress and feel accomplished.

The patterns identified in the inductive analysis were mirrored in the deductive analysis. The most frequently coded Octalysis core drives were *Development & Accomplishment* (n = 159) and *Empowerment of Creativity & Feedback* (n = 116), reflecting users' appreciation for structured goal setting, visible progress, and the ability to personalize their engagement. In addition, *Epic Meaning & Calling* (n = 78), *Ownership & Possession* (n = 73), and *Social Influence & Relatedness* (n = 29) were recurring themes in the data, indicating that users also found value in purpose-driven actions, a sense of personal responsibility, and moments of social connection.

By contrast, *Unpredictability & Curiosity*, *Scarcity & Impatience* and *Loss & Avoidance* were not coded at all, suggesting that these more extrinsically oriented or negative-motivation drives were absent from user perceptions.

The co-occurrence analysis of gamified features and Octalysis core drives further supports the thematic findings (see Table C4). The strongest alignment was observed between *Challenges/Goals and Development & Accomplishment* (n = 59), followed by *Empowerment of Creativity & Feedback* (n = 26), indicating that structured goal setting is perceived as both progress-oriented and autonomy-supportive. *Progress Tracking* similarly co-occurred most with *Development & Accomplishment* (n = 35) and to a lesser extent *with Empowerment of Creativity & Feedback* (n = 14), reinforcing its motivational role. While *Points* and *Levels/Badges* were rarely mentioned (n < 5), when they were, they still co-occurred with *Development & Accomplishment*, suggesting these elements are seen as reinforcing achievement. Additionally, *Ownership & Possession* frequently co-occurred with *Progress Tracking* and *Carbon Progress*, suggesting that users felt a sense of control and pride over their environmental actions. *Social Influence & Relatedness* appeared mainly in connection with Community Engagement, reflecting how shared purpose and visibility of others' actions reinforced motivation.

These results suggest that structured, progress-oriented features are central to user engagement. Their connection to intrinsic motivation will be discussed in Section 5.1.

4.1.2 Guided & Goal-Oriented Action

While the previous section focused on gamified elements, the next theme examines how the app guides users through goal-directed behavior. Similarly to the previous theme, three key codes were developed: *Accountability, Actions and Technical Tracking*.

Users often described the app as helping them stay on track with personal goals while offering actionable steps that feel achievable. *Accountability* (n = 142) emerged as one of the strongest patterns, with users frequently highlighting how the app's reminders, timelines, and progress feedback supported follow-through. This theme was further divided into four interrelated subcodes, each representing a distinct layer of perceived support. *Awareness & Realization* (n = 81) captures comments in which users became more conscious of their carbon footprint or daily habits, often marking the starting point for behavioral change. *Reminder-Based* (n = 25) denotes

explicit mentions of notifications, timelines, or widgets that nudge users back to their goals. *Goal-Linked (*n = 26) encompasses references to setting, reviewing, and achieving specific targets:

"It also lets me set an annual target […] review and refine my actual emissions." (G030).

Finally*, Personal Reflection & Empowerment* (n = 27) reflects deeper insights and emotional shifts, where users articulate how the app fostered a sense of agency. Together, these subcodes illustrate how EarthHero not only informs and reminds but also empowers users to translate awareness into sustained, goal-oriented action.

Actions were at the core of the user experience and were widely praised for their clarity and accessibility, making this one of the most frequently coded aspects of the dataset (n = 170. Three specific dimensions emerged within this pattern: (1) *Accessibility & Simplicity* (n = 69), (2) *Clarity & Detail* (n = 32), and (3) *Variety & Flexibility* (n = 84).

(1) Simplicity: Many users valued the ease of getting started.

"This app shows me little things I can do to help the environment… It's helping me change for the better." (G006)

(2) Detail: Users appreciated how each action was explained and backed up by resources.

"Each action has a description and points to places where you can learn more." (G036)

(3) Flexibility: The wide range of actions, categorized by difficulty and impact, was viewed as empowering.

"Huge list of climate action ideas to choose from — something for everyone, no matter where you are on your journey." (G003)

In addition to the appreciation for the structured actions provided by the app, several users noted a particular feature: the ability to submit their own actions for review and potential inclusion in the app. While this aspect did not emerge as a coded theme, it appeared in analytic memos as a noteworthy sentiment.

Technical Tracking (n = 41) refers to how users experienced the app's carbon footprint and emissions tracking tools in a functional and evaluative sense and not just as sources of motivation, but as reliable systems for monitoring their environmental impact. Users frequently highlighted the app's precision, usability, and clarity in calculating emissions based on real lifestyle data. Many

emphasized that this functionality helped them trust the information provided, compare their output to global benchmarks, and make data-informed choices. Several reviews also mentioned that EarthHero's tracking system was more detailed or accurate than other tools they had used:

"Earth Hero is the best app for tracking & recommending sustainable actions. It's the most accurate carbon calculator so far." (A223).

These findings suggest that EarthHero's reminders, goal tools, and diverse action options were seen as key supports for sustainable habits.

4.1.3 Empowerment & Motivation

Beyond structure and support, many users also described emotional and psychological benefits from using the app, which are explored in this theme. It captures the emotional and psychological responses users had to using EarthHero, particularly feelings of empowerment, sustained motivation, and climate-related relief.

Empowerment / Hope / Confidence (n = 101) emerged as a central experience, especially among users who felt the app helped them shift from concern to action. For many, this was not only about knowledge but also about emotional agency:

"An inspiring and brilliant way to develop your own climate action plan. Taking action was never so easy. Gives me hope for a better future." (G049).

Empowerment: Easy to Use (n= 55), reflected appreciation for the app's simplicity and practicality. These comments often overlapped with earlier action-related codes but emphasized personal ability:

"This app makes it so easy to take steps, big and small, to combat our climate emergency."
(A071).

Autonomy (n = 27) also featured prominently in the user reviews. Users value being able to choose actions that fit their lifestyles and goals, reinforcing intrinsic motivation and a sense of control:

"I like that you can choose the actions suited to your circumstances." (G194).

Moreover, the app's overall affective presentation coded under *Perceived Design Tone* (n = 18) was mentioned as a key motivator. Users noted that EarthHero avoided guilt-based messaging and instead fostered a constructive atmosphere:

"I like the initial measurement of emissions & the delivery of that information not being scornful, but instead with the hope that this knowledge will increase awareness & motivate the user to make better choices that will impact their measurement." (A064)

Climate Anxiety Relief (n = 29) was also mentioned when users described the emotional impact of seeing progress or receiving encouragement:

"When I'm feeling sort of down or hopeless about climate change, this app lays out everything, and shows me all the things I'm doing AND how I can improve!" (G309)

A smaller but meaningful pattern also emerged around *Empowerment through Collective Action* (n = 24), where users expressed feeling part of a larger movement or community working toward climate solutions. This experience aligns with the Octalysis core drives *Epic Meaning & Calling* and *Social Influence & Relatedness*, as it reflects motivation rooted in shared purpose and social connection. These comments suggested that motivation was not only derived from personal progress, but also from contributing to collective goals and broader environmental values:

"I feel a part of something bigger with Earth Hero" (A096).

The emphasis on autonomy, positive reinforcement, and meaningful contribution differentiates it from more fear- or obligation-driven approaches. These findings also intersect with ethical perceptions, explored further in *section 3.2*. These insights are revisited in relation to ethical and motivational design in the discussion.

4.2 Ethical Implications of Gamification Design

This section explores how users evaluated the ethical dimensions of EarthHero's design. While ethical concerns were not a dominant theme across reviews – as illustrated in Figure 1 when comparing to the other themes - several recurrent patterns emerged which highlighted both positive perceptions and critical reflections. In total, 46 coded instances were identified across six inductive codes, all grouped under the overarching theme *Ethical and Emotional Implications.*

Some users expressed concerns about the app's inclusiveness or contextual relevance, which were coded *under Contextual Misalignment & Inaccessibility* (n = 19). These comments reflected mismatches between the app's action suggestions and users' living situations, age, or physical constraints:

"Many of the actions also seem urban-, youth- and able-body oriented. That's ok, but those just don't apply." (A019).

Contrary to this, another recurring pattern was the *code Positive Ethical Perception* (n = 25), in which users explicitly praised the app's ethical design choices. This included appreciation for the inclusiveness of its actions, as well as the absence of advertisements, payment barriers or monetized features. As one user stated:

"This app does not try to sell anything, or make you "purchase your carbon" it gives actionable steps to help the climate." (A106).

These comments suggest a perception of EarthHero as transparent, non-exploitative, and respectful of its users.

Critical perceptions about the app's carbon tracking logic were captured under *Data Accuracy Concerns* (n = 13). While some users questioned how their environmental impact was calculated, these comments typically reflected a desire for greater transparency, more detailed input options, or better contextual alignment rather than outright distrust. In this sense, users were calling for refinement and clarity in the app's methodology. As one user noted:

"Measuring emissions is nuanced and no app will get it 100% right (in particular, I'd like more visibility of assumptions re. number of household members, and better granularity of options re food consumption) but this app makes a great start." (G105).

A smaller number of users provided critiques of gamified and motivational features, coded as *Motivation Design Critiques* (n = 9). While many users found reminders helpful, others found them inconsistent, intrusive, or lacking customization. Some users highlighted broader motivational limitations, including the absence of collaborative or social features, difficulty completing challenges, frustration with inflexible goal structures, and demotivation caused by rigid input questions or overly simplified assumptions. This suggests opportunities for improving the

responsiveness and flexibility of motivational tools. However, the limited number of comments makes it difficult to determine whether these issues reflect broader ethical concerns.

Finally, a few reviews raised direct concerns related to privacy and account creation, coded as *Ethical Concerns / Trust* (n = 2). Though very minor, these comments indicate potential sensitivity around data governance.

Only a limited number of user comments overlapped with the ethical dimensions defined by the 7PD. The *Data Accuracy Concerns* code aligned clearly with the *Data Integrity* domain, which addresses transparency, reliability, and the respectful handling of user data. Additionally, two instances within *Motivational Design Critique* corresponded to the *Motivation* (n=2) domain, specifically when design elements such as reminders were perceived as demotivating or intrusive.

In contrast, the remaining 7PD domains were not reflected in the dataset. This absence could suggest that users did not perceive the app as ethically problematic in ways captured by the 7PD framework. As such, the concerns identified were narrow in scope and focused primarily on issues of design fairness and data transparency, rather than on deeper ethical violations related to manipulation, surveillance, or exploitation.

While ethical concerns were limited, emerging patterns suggest inclusivity and design fairness are key user priorities. Their implications will be explored further in Section 5.2.

5. DISCUSSION

This study set out to explore which aspects of gamified app design users find most engaging and how they reflect on the ethical dimensions of these features. The following section connects the findings to existing literature and examines them through the lens of the theoretical frameworks applied in this research.

5.1 Effectiveness of Gamification features

While classic gamification literature often emphasizes extrinsic elements such as badges, points, and levels (Abdul Rahman et al., 2018; Hallifax et al., 2023; Khaldi et al., 2023), these features had limited motivational relevance for EarthHero users. Few reviews mentioned these features (n < 5), suggesting they were either too subtle or not salient enough to drive engagement. When referenced, they were still associated with the core drive *Development & Accomplishment* (see co-occurrence analysis, Table C4) highlighting how extrinsic tools can support intrinsic motivation in the right context. It also raises the question of whether certain design elements can be motivational without being consciously recognized. This underlines the importance of complementing user perception with theoretical frameworks to fully understand how gamification features operate beneath awareness, particularly in the case of nudging or persuasive design strategies.

In contrast, users consistently praised goal setting, challenges, reminders, and progress tracking which are features that reflect intrinsic motivators such as autonomy, competence, and purpose. These preferences align with findings from Miao et al. (2022) and were further supported by the co-occurrence analysis (see Table C4), which showed strong links between these features and the core drives *Development & Accomplishment* and *Empowerment of Creativity & Feedback*. *Challenges/Goals* and *Progress Tracking* most frequently aligned with *Development & Accomplishment* which highlights how users consistently associate structured progression with a sense of achievement. Similarly, *Empowerment of Creativity & Feedback* frequently co-occurred with customizable features, underscoring the importance of autonomy-supportive design. This pattern reinforces the interpretation that EarthHero's motivational design is driven less by isolated game mechanics and more by the integrated experience of autonomy, structured progression, and emotional validation. The lack of black hat drive associations (e.g., scarcity) supports the app's

focus on intrinsic motivation over urgency. These results suggest a deliberate design architecture in which even subtle features (e.g., reminders, emissions graphs) are embedded in psychologically coherent motivational systems. It also supports earlier research suggesting that sustainability-related behaviors are more effectively encouraged through intrinsic, rather than extrinsic motivators (Ouariachi et al., 2020; Sailer et al., 2017).

Notably, customizable action options and flexible goal structures were particularly valued, emphasizing the role of autonomy in sustaining user engagement. This suggests that EarthHero's motivational impact may stem less from its game mechanics and more from its ability to provide clear, personalized, and achievable steps toward climate action. The high frequency is also consistent with prior research stressing the importance of user-centered design in sustaining engagement (Ouariachi et al., 2020). Given that autonomy, competence, and relatedness are critical to fostering intrinsic motivation (Sailer et al., 2017), it is not surprising that customizable, non-prescriptive action features were especially valued by users.

Users' engagement with carbon tracking aligns with the core drive *Ownership & Possession*, as it fosters a sense of control over one's impact and reinforces commitment through perceived personal ownership. Although the concept has been critiqued for its origins in corporate efforts to individualize responsibility (Solnit, 2021), its use within EarthHero appears to foster a productive sense of accountability. Seeing personal progress appears to help users internalize climate action as something they actively own, rather than passively observe, suggesting that even contested concepts can serve as meaningful engagement tools when paired with well-designed feedback.

Overall, EarthHero's design strongly emphasized white hat motivators, those associated with intrinsic satisfaction and long-term engagement while avoiding black hat motivators like scarcity, unpredictability, or fear of loss. This approach aligns with broader trends in sustainability apps (Ouariachi et al., 2020) and reflects a deliberate commitment to user-centered, ethical engagement. However, this design trend raises a critical question shared by previous research: Can a purely white hat approach generate the emotional urgency required for large-scale climate action? This highlights the for further research to evaluate if there could be a potential design trade-off between ethical comfort and the intensity sometimes needed to catalyze rapid behavioral change.

Closely related to this is the role of technical tracking in building user trust. Many users praised the app's carbon tracking tools for their precision, clarity, and usability. The ability to calculate

personal emissions, monitor reductions over time, and compare performance to global or national benchmarks reinforced the app's credibility. These features were not only seen as useful but as essential to validating progress and enhancing commitment. Trustworthy feedback fosters both motivation and confidence in the app's design. However, as a few users pointed out, a lack of transparency in the underlying calculations led to uncertainty about data accuracy which suggests that even well-received tracking tools must ensure methodological clarity to maintain trust.

Beyond functionality, many users described the app's emotional benefits. EarthHero's calm design and actionable steps helped reduce climate anxiety and foster agency. Users reported feeling empowered and hopeful. This is essential when addressing wicked problems like climate change, where individual action often feels futile (Grint, 2024). By presenting users with clear, attainable steps and avoiding alarmist messaging, the app appears to counter this mindset and foster a sense of psychological agency. Additionally, some reviews emphasized the value of collective engagement. References to shared purpose and global community reflected the core drives *Epic Meaning & Calling* and *Social Influence & Relatedness*. These perceptions not only enhanced motivation but also positioned users as active participants in a broader climate movement which is an important factor in sustaining long-term behavior change and countering feelings of isolation or helplessness (Grint, 2024).

5.2 User Perceptions of Ethical Design

A central finding of this study is the relative absence of explicit ethical concerns in user reviews. While some critiques emerged, they did not align neatly with the categories outlined in the 7PD. For example, concerns about contextual misalignment, such as actions being unrealistic due to users' living situations or abilities, surfaced repeatedly, highlighting a gap in the 7PD's scope. Although raised by a minority of users, such concerns point to broader issues of fairness and accessibility. However, this was contrasted by two prominent and frequently occurring codes: Positive Ethical Perception and Actions: Accessibility & Simplicity, both of which show that most users experienced the app as inclusive and approachable. This suggests that while a subset of users faced contextual barriers, the overall design was widely perceived as accessible. Integrating principles from Inclusive Design and Design Justice (Costanza-Chock, 2020) could expand existing frameworks to better reflect the varied contexts in which users engage with gamified systems. Moreover, this finding aligns with Hill et al. (2013) who emphasize that sustainable

behavior is shaped not only by individual motivation but also by contextual factors such as social norms, physical environments, and available resources. Their work highlights how structural and situational barriers can limit an individual's ability to engage in sustainability actions, regardless of their intentions. This supports the present study's observation that ethical evaluations must account for contextual accessibility

One likely explanation for the limited presence of ethical concerns is the non-commercial nature of EarthHero. Ethical risks in app design often emerge when monetization or engagement-maximization objectives take precedence over user autonomy and well-being (Kim & Werbach, 2016). Furthermore, research shows that users rarely read privacy policies or terms of service and often accept data practices without scrutiny (Obar & Oeldorf-Hirsch, 2020). This inattentiveness may explain the lack of ethical concerns.

Nevertheless, it is worth noting that, in addition to positive perceptions of accessibility, some users explicitly praised the absence of advertisements and in-app payments, as well as the app's constructive and non-pressuring tone, suggesting that users did perceive the app on an ethical level and evaluated it mostly positively. As highlighted in the introduction, user-generated content such as app reviews can reveal ethical concerns that might not surface in traditional research settings (Schmidt-Kraepelin et al., 2019). These positive framings of EarthHero thus offer evidence of ethical design in practice, while also underscoring the need to broaden existing ethical frameworks like the 7PD.

Although gamification is often seen as persuasive technology, users did not perceive EarthHero as coercive which is likely due to its autonomy-supportive design (Kim & Werbach, 2016; Rozalén, 2024). Features like customizable goals, flexible actions, and user-submitted ideas promoted choice and personal relevance (reflected in the Octalysis core drive *Empowerment of Creativity & Feedback*), aligning with ethical motivational principles (Sailer et al., 2017).

In summary, the findings highlight that EarthHero's impact lies in its combination of structured goal setting, emotionally supportive design, and ethically considerate features. They support the broader argument that gamification can meaningfully promote PEB when it emphasizes intrinsic motivation and respects user agency. The conclusion will consolidate these insights, answer the research question directly, and propose directions for future research.

5.3 Practical Implications

Based on the findings, several recommendations emerge for the future design of sustainability-focused gamified systems.

First, designers should prioritize autonomy and personalization, enabling users to choose actions that align with their individual values, lifestyles, and capabilities. This supports intrinsic motivation and fosters long-term engagement. Moreover, white hat motivators, such as purpose, competence, and creativity, should be emphasized over pressure-based or extrinsic strategies, as these were consistently associated with positive emotional responses and higher engagement. Additionally, strong and detailed guidance should be prioritized in the design of action suggestions. Users valued clear, practical, and context-sensitive instructions that made it easier to translate intentions into concrete steps. Providing actionable and well-explained pathways can enhance users' sense of competence and lower the threshold for engagement, especially for individuals unfamiliar with sustainability practices.

5.4 Theoretical Implications

This study finds the Octalysis Framework to be a strong fit for analyzing motivational design in sustainability apps. It effectively captured user perceptions of autonomy, progress, and purpose, aligning with prior research. However, the role of black hat motivators such as scarcity or unpredictability remains unclear and warrants further research to assess both their effectiveness and ethical implications. The 7PD, by contrast, were less applicable in this context. Moreover, the 7PD might be less relevant for evaluating non-commercial apps like *EarthHero*, where ethical risks linked to monetization and data exploitation are minimal which highlights a potential need for adapting or supplementing the framework in such contexts. Inclusivity emerged as a central ethical concern: users frequently highlighted the importance of accessible, context-sensitive design. Future frameworks for gamification ethics to be used in research should account for design inclusiveness and contextual fit as key evaluative dimensions.

5.5 Transdisciplinary Research

While this study engages with real-world sustainability challenges, it is not considered transdisciplinary, as it does not actively involve stakeholders or integrate non-academic perspectives in the research process. The choice of a qualitative case study based on user data

limited opportunities for collaboration beyond the academic context. This decision was guided by methodological feasibility and discussed with the supervisor. However, future studies could complement these findings by involving app users, designers, or policymakers directly. For example, by collaborating with the case study organization to share results and gather feedback, or by actively involving the company through interviews and collaborative discussions. Such approaches could offer deeper insights into how ethical and motivational considerations are negotiated in practice and enhance the societal relevance and impact of gamified sustainability interventions.

5.6 Limitations

The in-depth analysis of a single PEB provides valuable insights but it limits the generalizability of its findings (Yin, 2018)

While predefined inclusion criteria were applied to reduce bias, user reviews remain subject to self-selection and limited context. As such, the findings should be interpreted with caution as reflective of subjective user perceptions rather than objective truth.

The dataset also included only U.S.-based reviews, which may have shaped user perceptions. A more diverse, international sample could reveal differing motivations, expectations, or ethical concerns (Fischer et al., 2021), enhancing the transferability of findings.

Technical limitations further constrained the dataset. Apple App Store reviews were pre-filtered by Apple, and reviews from the Google Play Store may also reflect platform-specific biases. As writing a review is itself an in-app action, some users may have been motivated by rewards rather than authentic engagement. While low-quality reviews were excluded, some may still reflect early impressions or incentive-driven feedback.

6. CONCLUSION

This study aimed to answer the question: "What gamification elements are perceived as effective in promoting pro-environmental behavior, and how do users evaluate their ethical implications?".

Using a case study of the EarthHero app, 425 user reviews were thematically analyzed through a hybrid inductive-deductive approach. The Octalysis Framework was applied to deductively identify which motivational core drives users associated with the gamification elements and the app overall, while the 7PD were used to examine ethical issues.

In response to the first part of the research question, findings indicate that users most positively evaluated features related to goal setting and progress tracking features. These elements promote autonomy and are primarily associated with white hat motivators in Octalysis, particularly *Development & Accomplishment* and *Empowerment of Creativity & Feedback*. Users also appreciated the flexible action choices, which again highlights autonomy as a highly valued aspect. In contrast, traditional elements such as points and levels received little attention, suggesting that these extrinsic rewards are less valued in the context of sustainability apps. Instead, users emphasized the importance of simplicity, visual clarity, and a non-judgmental tone, which contributed to feelings of empowerment and reduced climate anxiety.

Addressing the second part of the question, users generally perceived EarthHero as ethically designed. Key strengths included its autonomy-supportive structure, non-commercial model, and absence of advertisements or coercive tactics. While most users found the app inclusive and accessible, some noted limitations related to physical ability, living situation, or socio-economic context. These concerns suggest that inclusivity is a relevant ethical dimension in the design of PEB apps. Overall, the lack of strong ethical critique likely reflects EarthHero's specific design choices, rather than the absence of ethical risks in gamified systems for sustainability more broadly.

One of the strengths of this study lies in its use of real-world user feedback to evaluate both motivational effectiveness and ethical perceptions, offering an applied lens on theoretical models. The hybrid coding approach allowed emergent and theory-driven insights. Focusing on a single, non-commercial app provided depth and contextual richness, which is often missing in broader reviews. This is especially pertinent given that gamification for PEB remains a developing field.

The findings provide practical guidance for designers and researchers aiming to create ethical, engaging gamified systems that empower users to act on climate change. The study not only identifies which gamification elements most effectively motivate users but also offers insights into how these features can be implemented and supplemented to maximize their impact. Future research should build on the implications of this study to expand the research by comparing multiple apps across diverse cultural and demographic contexts and by incorporating interviews to validate and deepen review-based findings. Additionally, it would also be valuable to refine ethical frameworks like the 7PD to better capture user concerns in sustainability apps.

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Appendix A: Supplementary Materials – Methods and App Interface

Figure A1: App Selection and Data Cleaning Process

This flowchart illustrates the multi-step process used to identify, screen, and select the final app (EarthHero) for the analysis. It also outlines the stages of app review extraction and data cleaning that led to the final dataset of 425 user reviews included in the thematic analysis.
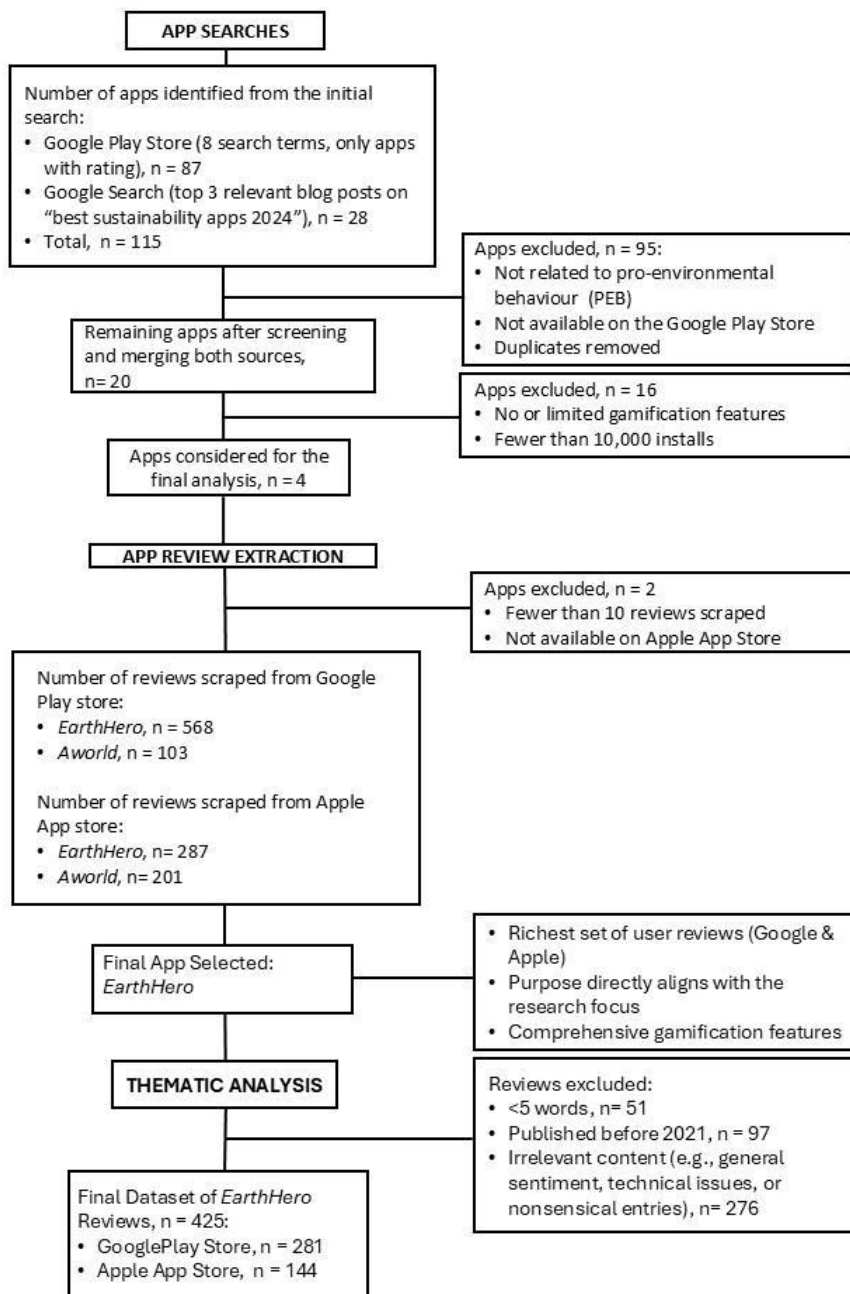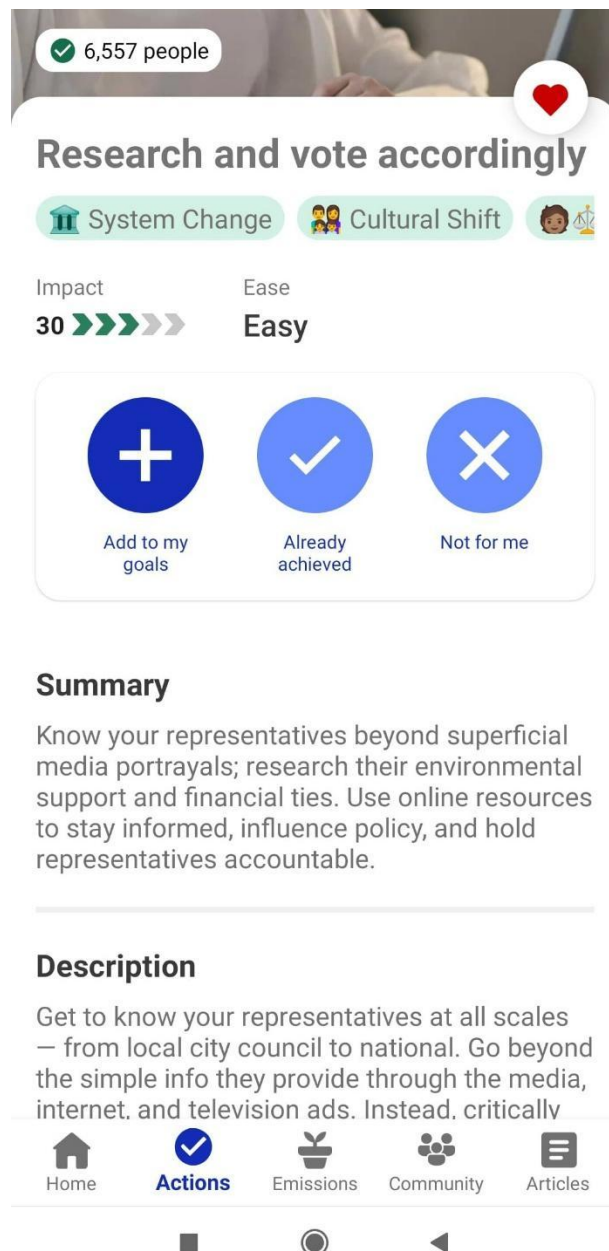
Figure A2: Example of a Goal-Oriented Action ("Research and vote accordingly")

This figure shows a sample action in the EarthHero app, including its impact rating, ease level, and user interaction buttons ("Add to my goals", "Already achieved", "Not for me"). It also displays the summary and description text supporting the action, illustrating EarthHero's structured guidance and accessible language.

✅ 6,557 people

❤️

Research and vote accordingly

🏛 System Change   👨‍👩‍👧 Cultural Shift   🧑🏾‍⚖️

Impact	Ease
30 ›››››	**Easy**

➕ Add to my goals   ✔️ Already achieved   ✖️ Not for me

Summary

Know your representatives beyond superficial media portrayals; research their environmental support and financial ties. Use online resources to stay informed, influence policy, and hold representatives accountable.

Description

Get to know your representatives at all scales — from local city council to national. Go beyond the simple info they provide through the media, internet, and television ads. Instead, critically

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internet, and television ads. Instead, critically research how often your representatives support environmental bills, who they take money from, and how much they are a part of real solutions.

It generally does not take that long, actually. You will get to know who they are, and it might surprise you what they support. It makes you a more informed voter and helps when discussing candidates with friends and family. Check out the official website of your representatives and search for trusted independent sources about their records and positions on critical issues.

Even if your representatives do not support all or any that you hoped for, finding out what does matter to them can help you link climate change and the environment to their concerns. Creating positive change often means bringing people with related concerns together to make things happen.

Notes

Add your private notes here.

⬆️

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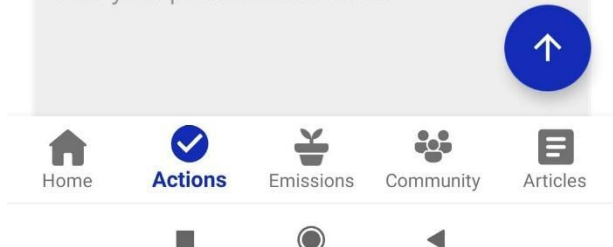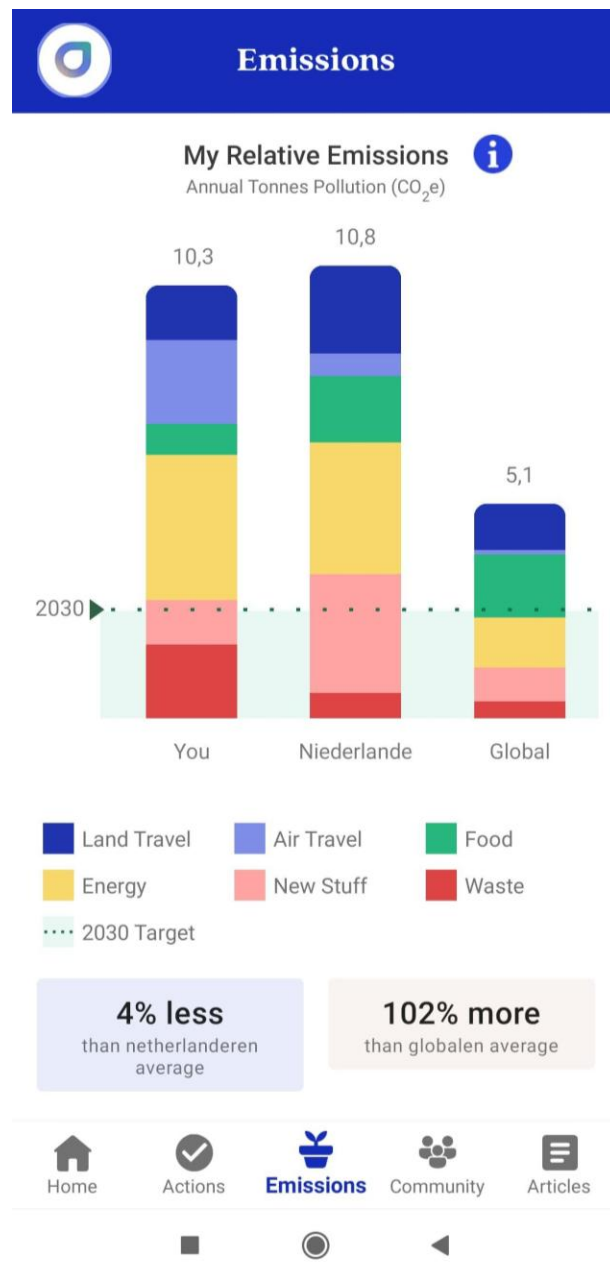
Figure A3: Emissions Feedback and Goal Comparison Interface

This figure displays the emissions dashboard in EarthHero, comparing a user's carbon footprint to national and global averages.

Source: Screenshots from EarthHero app, accessed April 2025. (All screenshots are taken from the publicly available EarthHero app and do not display any user-identifiable data.)

Appendix B: Python Scripts for Scraping EarthHero Reviews

Appendix B1: Google Play Store Scraper (Python)

The following script collects up to 2,000 user reviews of the EarthHero app from the U.S. Google Play Store using the google-play-scraper library. It removes duplicates, filters short entries, and exports the data as a CSV file.

```
!pip install google-play-scraper

import pandas as pd


app_id= 'com.earthheroorg.earthhero'


from google_play_scraper import reviews, Sort


all_reviews = []

seen_review_ids = set()

MAX_REVIEWS = 2000

last_batch_ids = set()

countries = ["us"]


for country in countries:

    token = None

    while True:

        result, token = reviews(
```

```python
        app_id,
        lang="en",
        country=country,
        count=200,          # Max per request
        sort=Sort.MOST_RELEVANT,
        continuation_token=token
    )

    current_batch_ids = set([r["reviewId"] for r in result])

    if current_batch_ids == last_batch_ids:
        print(f" Repeated batch detected in {country}. Ending loop.")
        break
    last_batch_ids = current_batch_ids

    new_reviews = []
    for review in result:
        content = review["content"]
        word_count = len(content.split())


        if review["reviewId"] not in seen_review_ids and word_count > 5:
            seen_review_ids.add(review["reviewId"])
            new_reviews.append({
```

```python
                "reviewId": review["reviewId"],

                "content": review["content"],

                "score": review["score"],

                "reviewCreatedVersion": review["reviewCreatedVersion"],

                "at": review["at"],

                "country": country

            })


    all_reviews.extend(new_reviews)

    print(f"Collected: {len(all_reviews)} reviews...")


    if not new_reviews or not token or len(all_reviews) >= MAX_REVIEWS:

        break


df = pd.DataFrame(all_reviews)


# Drop duplicate reviews based on 'reviewId' or full 'content'

df = df.drop_duplicates(subset="reviewId")

# OR

# df = df.drop_duplicates(subset="content") #if reviewId is missing or not unique


# Export

df.to_csv(app_id + "_reviews_deduped.csv", index=False, sep=';', encoding="utf-8")

print("Done.")
```

Appendix B2: Apple App Store Scraper (Python)

This script collects reviews of the EarthHero app from the U.S. Apple App Store using the app-store-scraper library. It filters duplicates and short entries, sorts by date, and exports the cleaned data as a CSV. As of June 2025, the scraper may no longer return data due to changes in Apple's API or review availability.

```
!pip install app-store-scraper


from app_store_scraper import AppStore

import pandas as pd


app_name= "earth-hero-climate-change"

app_id= 1458057746


app = AppStore(country="us", app_name=app_name, app_id=app_id)

app.review(how_many=1000)


df = pd.DataFrame(app.reviews)


#  Remove duplicates based on review content

df = df.drop_duplicates(subset='review')


# remove very short reviews

df = df[df['review'].str.split().str.len() > 5]


df['date'] = pd.to_datetime(df['date'])
```

```python
# Sort by date (newest first)

df = df.sort_values(by='date', ascending=False)


# Save sorted DataFrame

df.to_csv(app_name + "(apple store) reviews.csv", index=False, sep=';', encoding="utf-8")


print("Done.")
```

Appendix C: Thematic Analysis – Code Tables and Co-Occurrence Data

The full dataset of user reviews analyzed in this study is available at the following link: https://docs.google.com/spreadsheets/d/178n8hEsv_45jfzmIOWBthMACWDCN9Kmov5dMgS AkHzY/edit?usp=sharing. This dataset includes all raw user reviews analyzed in this study, along with associated review IDs, dates, and platform identifiers.

Table C1: Thematic Codebook Overview (inductive)

This table summarizes all inductive themes, codes, and subcodes, including descriptions, frequencies, and example quotes to illustrate key patterns.

Theme	Code	Description of the Code	Example Quotes	Frequency
Motivational Design / Gamification Analyzes how the app uses gamified elements to motivate users (such as rewards, points, social comparison, autonomy, progress bars, challenges, and fun mechanisms)	Community Engagement	Users mention value in shared actions, peer motivation, or community features.	"Gratifying to be part of a global community of climate heroes to mindshare and learn how to make a collective impact." (A175)	15
	Gamified Elements	References to gamification elements.	— (see subcodes below)	150
	Challenges/Goals	Mentions of specific tasks, missions, or goal-driven structure.	"Being able to set reasonable and realistic goals to work towards also helps make conscious living less stressful..." (G008)	75
	Fun / Enjoyment	Users enjoy the experience and mention fun as a motivator.	"I love marking actions I do." (G021)	29
	Gamification	Broad references to gamified structure, game-like design, or game feel.	"An awesome way to gamify sustainable habits." (G040)	5
	Levels/ Badges	Users refer to progress levels or badge systems.	" […] rates [actions] for you in return for badges!" (G019)	4
	Points	Mentions of point scoring, tallying, or point-based rewards.	"[..] Earth Hero makes eco-friendly lifestyle changes into a little game where you earn points for each new step you take!" (A062)	5
	Progress Tracking	Users track environmental impact or behavioral data over time.	"The progress tracking feature is superb and very motivating." (G021)	44
	Visual feedback	Graphs, charts, or visuals provide performance or impact feedback.	"I find the way it's set up very motivating since it shows you a graph of reductions you've made over time" (G246)	17
	Perceived Impact	Refers to users' reflections on the tangible or emotional significance of their actions within the app	— (see subcodes below)	81

Table C1 (Cont'd): Thematic Codebook Overview (inductive)

Theme	Code	Description of the Code	Example Quotes	Frequency
Motivational Design / Gamification Analyzes how the app uses gamified elements to motivate users (such as rewards, points, social comparison, autonomy, progress bars, challenges, and fun mechanisms)	Achievement Recognition	Users feel acknowledged or proud of their accomplishments.	" [...] being able to look back and give myself credit for all my efforts and to look forward to concrete goals." (G022)	23
	Carbon Progress	References to measurable carbon footprint reduction or tracking.	"[...] makes it easy to track your efforts towards action against climate change. You can set and achieve small personal goals to improve your carbon footprint." (G077)	44
	Comparative Impact Awareness	User compares own behavior with others or broader standards.	"Graphs that compare your own output to the rest of the world help you understand where you personally are having the biggest effect." (G085)	19
Guided & Goal-Oriented Action Focuses on how the app guides users through sustainable behaviors by offering structured actions, clear goals, step-by-step suggestions, and progress tracking	Accountability	User reflects on personal responsibility or feels the app prompts responsible behavior.	— (see subcodes below)	142
	Awareness & Realization	The app increases awareness of environmental impact or personal habits.	"Helps me understand my carbon footprint and how I can make my life better." (G003)	81
	Goal-Linked	Behavior is tied to specific goals or targets set by the app.	"It also lets me set an annual target. I was able to review and refine my actual emissions [...]" (G003)	26
	Personal Reflection & Empowerment	Users describe feeling empowered through self-reflection and agency.	"It gives you actions to improve upon and it makes you conscientious of all the changes [...]" (G042)	27
	Reminder-Based	Users are motivated by reminders or nudges to stay accountable.	"Complete with the option to set up a timeline and reminders [...]" (G030)	25
	Actions	General references to app-provided actions, task suggestions, or action-based structure.	— (see subcodes below)	170
	Accessibility & Simplicity	Users find the actions easy to understand, low-barrier, and user-friendly.	"Great having very simple tasks included – can knock off a bunch to help build momentum for the bigger issues." (G151)	69
	Clarity & Detail	Users value detailed instructions or informative descriptions for each action.	"Each action has a description and points to places where you can learn more." (G036)	32
	Variety & Flexibility	App offers a broad and flexible selection of actions to choose from.	"Huge list of climate action ideas to choose from." (G003)	84
	Technical Tracking	App provides structured tools or dashboards to monitor behavior or emissions.	"You can get statistics on your own carbon emissions and add goals on how to reduce them [...]" (G056)	41

Table C1 (Cont'd): Thematic Codebook Overview (inductive)

Theme	Code	Description of the Code	Example Quotes	Frequency
Empowerment, Emotional Safety and Tone Covers how users emotionally experience the app's design — whether it feels encouraging, non-judgmental, accessible, and empowering to take action without fear, guilt, or overwhelm.	Autonomy	Users value the ability to choose actions freely or feel ownership over their behavior.	"Instead of being overwhelmed [...] this app provides actionable information on how to make changes at your own pace." (G062)	27
	Climate Anxiety Relief	App helps reduce stress, guilt, or fear related to environmental responsibility.	"It's easy to use and helps me reduce my anxiety by giving me things I can actually do!" (G230)	29
	Empowerment / Hope / Confidence	Users describe feeling capable, inspired, and optimistic through the app.	"Earth Hero has been a great guide to help me figure out how to live more sustainably and make a difference." (G001)	101
	Empowerment Through Collective Action	Emphasis on shared purpose or collective engagement in climate action.	"I feel a part of something bigger with Earth Hero" (A096).	24
	Empowerment: Easy to Use	Users feel the app's simplicity supports their sense of competence and agency.	"This app makes it so easy to take steps, big and small, to combat our climate emergency." (A071)	55
	Perceived Design Tone	Perceptions of tone—non-judgmental, supportive, empowering rather than alarming.	"I appreciate the developers thoughtfulness in not being too pushy, yet very helpful." (A086)	18
Ethical & Emotional Implications Captures users' concerns, critiques, and reflections on ethical issues like data privacy, manipulation, fairness, accessibility, and the emotional consequences of app design.	Contextual Misalignment & Inaccessibility	Users feel the app's content or actions don't fit their lifestyle, region, or situation.	"Wish certain things like apartment living (thus making lawn care, electricity source switching, etc. not applicable in many cases) could be accounted for in the emissions count." (G336)	19
	Data Accuracy Concerns	User critiques on the precision, granularity, or transparency of emissions calculations. Often reflect a wish for more detailed or personalized inputs.	"Measuring emissions is nuanced and no app will get it 100% right (in particular, I'd like more visibility of assumptions re. number of household members, and better granularity of options re food consumption) but this app makes a great start." (G105)	13
	Ethical Concerns / Trust	Users express distrust toward the app's data policies or developer intentions.	"The developers claim this is not just a data collection app and they don't sell information. I don't believe them. For starters, why do I need to create an account with my email address? Why would that be 100% necessary for me to just see a list of some helpful ways I can change my lifestyle to reduce my footprint?"	2
	Motivation Design Critique	Users find the app's motivational features (e.g., reminders, challenges, progress tools) ineffective, annoying, intrusive, vague, or lacking.	"[...] deleting the app because the notifications are reaching spam levels. I generally like this app, except for the 30 Day Challenge. [...] no way in the challenge to mark them as complete. Instead, each day I just get additional notifications that the challenges for days 1, 2, 3, 4 etc are ready. There also doesn't appear to be a way to opt out of the 30 Day Challenge once started." (G051)	9
	Positive Ethical Perception	This code captures user expressions that frame the app's design as ethical, inclusive, and trustworthy	"This app does not try to sell anything, or make you "purchase your carbon" it gives actionable steps to help the climate." (A106).	25

Table C2: Thematic Codebook Octalysis Framework (deductive)

Code	Description of the Code	Example Quotes	Frequency
Epic Meaning & Calling	This Core Drive was coded when users expressed feeling that their actions contribute to a larger cause It reflects a sense of purpose, contribution to global impact, and being part of a collective movement.	"It motivates me to take meaningful actions to help save our planet." (G024)	78
Development & Accomplishment	This Core Drive was coded when users mentioned features that enabled them to set goals, track progress, and feel a sense of achievement.	"The progress tracking feature is superb and very motivating. I love marking actions I do." (G021)	159
Empowerment of Creativity & Feedback	This Core Drive was coded when users highlighted the app's flexibility, range of action options, and ability to personalize their experience.	"I love how user-driven it is. You can do the actions that work for you and even submit your own actions to help others become more sustainable." (A085)	116
Ownership & Possession	This Core Drive was coded when users referred to personal accountability, customization, and the ability to track and influence their own environmental impact. This included progress graphs, emissions estimators, and features allowing users to refine their own data.	"It's so eye-opening to actually see your carbon footprint like this, and it's extraordinarily fulfilling to see it shrink because of the app's wonderful advice." (A065)	73
Social Influence & Relatedness	This Core Drive was coded when users referred to community features, comparisons with others, or feeling part of a shared mission. It includes reviewing one's footprint relative to peers, engaging with climate action groups, or sharing the app with friends.	"It really makes you feel like you're part of a team and not alone in this giant issue." (A078)	29
Scarcity & Impatience	-	-	-
Unpredictability & Curiosity	-	-	-
Loss & Avoidance	-	-	-

Table C3: Thematic Codebook 7 Problem Domains (deductive)

Problem Domain	Description	Example Quote	Frequency
Competition and Collaboration	-	-	-
Data Integrity	Users expressed skepticism about the necessity of creating an account and questioned the app's claim not to collect or sell personal data	"Why do I need an account? I was just looking for an app to quickly compare the estimation of another app, just to realize that after downloading I can't use the app without an account." (G284)	2
Ethics & Exploitation	-	-	-
Manipulation	-	-	-
Motivation	Some users reported that overly frequent or inflexible notifications reduced their motivation and led to app deletion.	"[...] deleting the app because the notifications are reaching spam levells. I generally like this app, except for the 30 Day Challenge. The first few days are things I've already done but there seems to be no way in the challenge to mark them as complete. Instead, each day I just get additional notifications that the challenges for days 1, 2, 3, 4 etc are ready. There also doesn't appear to be a way to opt out of the 30 Day Challenge once started." (G051)	2
Surveillance & Privacy	-	-	-

Table C4: Co-Occurrence Matrix of Octalysis Core Drives and Gamification Elements

Octalysis
Core Drives →

Gamification Elements ↓

	Development & Accomplishment	Empowerment of Creativity & Feedback	Epic Meaning & Calling	Ownership & Possession	Social influence & Relatedness
Challenges/Goals	59	26	4	12	3
Gamification	1	2	0	1	1
Levels/Badges	4	1	0	0	0
Points	5	0	3	1	1
Progress Tracking	35	14	6	8	0
Visual feedback	11	1	0	7	3