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Recycle Tracker Application: A Gamified Mobile Platform to Enhance Recycling Behaviour

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Abstract - Malaysia's recycling efforts have long been challenged by limited accessibility, low motivation, and insufficient environmental awareness among the public. Despite various national campaigns, recycling participation rates remain inconsistent, highlighting the need for more engaging and user-centred approaches. To address these challenges, this paper presents the Recycle Tracker Application, a gamified mobile solution designed to encourage consistent recycling behaviour and strengthen environmental responsibility among Malaysians. The application integrates multiple core features, including a real-time interactive map of recycling centres, an educational waste-sorting and DIY recycling guide, personalized eco-goal setting, and an innovative Dino Evolution gamification system that rewards users as they progress. Developed using Flutter and Firebase technologies, the system allows users to record their recycling efforts, monitor progress analytics, set long-term environmental goals, and receive reminders that adapt to individual recycling patterns. User testing and survey results showed strong engagement levels, improved recycling knowledge, and higher motivation to recycle regularly. Participants reported that the gamification elements and visual feedback enhanced their sense of achievement and encouraged continued participation. The combination of behavioural nudges, interactive guidance, and personalized progress tracking proved effective in cultivating sustainable habits. Overall, the Recycle Tracker Application demonstrates that gamified digital solutions can serve as practical tools to promote environmental awareness and recycling participation. By fostering long-term behavioural change, the application contributes to Malaysia's broader efforts toward sustainable development and supports the transition to a circular and environmentally responsible economy.

Keywords—Recycling Application, User Engagement, Gamification, Mobile Application, Sustainable Waste Management, Recycling Awareness

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1. INTRODUCTION

Recycling plays a crucial role in reducing landfill waste, conserving natural resources, and mitigating environmental pollution. In recent years, global efforts have intensified to promote recycling as part of sustainable waste management practices. However, in Malaysia, recycling rates remain comparatively low. According to Bernama [1], the national recycling rate stood at only 31.52%, significantly lower than many developed countries where rates often exceed 60%. Despite long-standing government initiatives promoting the 3R concept—Reduce, Reuse, Recycle - public

participation in recycling activities remains limited. This low adoption rate highlights the urgent need to move toward a circular economy, which emphasizes reducing waste and keeping resources in use for as long as possible[2].

To investigate the factors contributing to low recycling participation and to identify potential strategies for encouraging sustained recycling behaviour, a survey was conducted with 60 Malaysian respondents. The survey examined respondents' perceptions, challenges, and motivational factors associated with recycling participation. Several key factors were identified from the results. Firstly, accessibility to recycling facilities is a significant concern. A total of 75% of respondents (45 out of 60) stated that knowing the location of the nearest recycling station is very important, highlighting the need for accessible and visible recycling options. This finding is consistent with Omran and Read [3], who reported that difficulties associated with recycling facilities and perceived inconvenience can contribute to low household recycling participation in Malaysia.

Secondly, a lack of knowledge regarding recyclable materials and proper disposal methods was evident. Over 96% of respondents rated their recycling knowledge as either basic (53.3%) or somewhat knowledgeable (43.3%), with only 3.3% considering themselves very knowledgeable. Additionally, 83.3% (50 out of 60) expressed interest in receiving tips and educational content related to recycling and sustainable practices. This aligns with Khalil et al. [4], who found that awareness of recycling consequences and a positive attitude significantly predict recycling intention, indicating that improving public understanding can lead to better recycling behaviour.

Lastly, low motivation and limited incentives were cited as major barriers to consistent recycling. Among the 19 non-recycling respondents, 78.9% (15 respondents) indicated that recycling is inconvenient or takes too much time, while 68.4% (13 respondents) cited a lack of motivation or perceived impact. Even among recyclers, 45% (27 out of 60) stated that reminders or habit-tracking features would help maintain their motivation. This is consistent with findings by Origi et al.[5], who reported that punitive measures alone, such as the threat of penalties, only explained 25% of recycling compliance. Beyond accessibility, the findings suggested that conventional approaches alone may not be sufficient to sustain recycling behaviour, highlighting the importance of alternative motivational strategies, such as positive reinforcement and engagement tools, to foster long-term recycling participation. These findings provided the behavioural rationale for the development of the proposed mobile application, which incorporates such motivational and engagement features to encourage continued recycling behaviour.

Mobile technology offers a promising solution to address these barriers. With the widespread use of smartphones, mobile applications can serve as convenient tools to improve accessibility, provide educational resources, and foster sustained user engagement. Moreover, integrating gamification elements into mobile applications has shown potential in influencing user behaviour by making recycling more engaging and rewarding[6], [7].

The main objective of this project is to develop a gamified mobile application, the Recycle Tracker Application, to enhance recycling behaviour in Malaysia. The application aims to (i) assist users in locating nearby recycling centres through real-time location mapping, (ii) provide educational resources to improve recycling knowledge, and (iii) incorporate gamification features such as eco-challenges and a Dino Evolution system to increase user motivation and sustained engagement.

The sections of this paper are organized as follows. Section 2 reviews existing recycling applications and user engagement strategies. Section 3 describes the system design of the proposed solution. Section 4 presents the system implementation with supporting interface designs. Section 5 is analysis and discussion. Finally, Section 6 concludes the paper with a summary and future recommendations.

2. LITERATURE REVIEW

This section reviews relevant literature and existing applications that support the development of the proposed solution. The discussion is organized into two main parts: user engagement in recycling, and a review of current recycling-related applications.

2.1 User Engagement in Recycling

User involvement plays an important role in ensuring that recycling applications are truly effective. When people stay engaged over time, they are more likely to turn occasional efforts into lasting habits, which are essential for creating

meaningful environmental change. However, many users encounter barriers such as confusion about correct recycling methods, a lack of awareness, or the feeling that their efforts do not make a real difference [8]. To overcome these challenges, recycling applications should make the process simple and rewarding. Users are more likely to keep recycling if they think their efforts are important, and this makes them recycle often.

Long-term engagement is very important, since recycling habits grow slowly through repeated actions. If users feel part of a larger community effort, they are more likely to keep these habits. So, long-term engagement is key to building steady recycling habits.

Gamification is one way to improve user engagement. It adds game-like features such as points, badges, and leaderboards to activities outside of games. These features make routine tasks more enjoyable and rewarding. They also give users incentives to stay committed to recycling [7]. Gamification creates both internal and external motivation. Users may feel satisfied when they help the environment. At the same time, they can earn points or badges. Together, these motivators encourage consistent participation [6].

Gamification has produced positive results in projects that focus on sustainability. For example, Gustafsson et al. [9] studied a mobile game designed to help teenagers and their families reduce home energy use. The game rewarded users for actions that saved energy. Their study found that gamification worked better when it included personalized feedback and competition. These features increased motivation by using social comparison and peer influence. In another study, Fitz-Walter [10] showed that location-based check-ins made a university orientation app more interactive and enjoyable for students.

The Mechanics-Dynamics-Aesthetics (MDA) model [11] is a useful framework for designing gamified systems. The model organizes user interaction into three linked layers: mechanics, dynamics, and aesthetics. Mechanics include the core features of the system, such as tracking recycling actions, giving points, and showing progress dashboards. Dynamics describe how users respond to these features over time, for example by keeping recycling streaks or aiming for long-term rewards. Aesthetics capture the emotions users feel, such as achievement, social recognition, or responsibility for the environment. When all three aspects are considered, gamified applications can improve both engagement and motivation.

Gamification is a powerful tool, but it is not the only way to encourage recycling. Non-gamification strategies are also important for building long-term habits [12]. A common method is nudging. Nudging uses simple prompts that guide users toward better choices without pressure. For instance, recycling apps may send push notifications to remind users of collection days. They may also give gentle suggestions on how to recycle items correctly.

Personalization is another effective way to promote recycling. Apps that adjust to users' preferences and habits can make the experience feel more meaningful. For example, showing users their personal recycling statistics can highlight their progress. Displaying the environmental impact of their actions can also build an emotional connection. These features help increase motivation and encourage users to continue recycling.

Making recycling simple is also important. Apps that use clear labels or simple icons can show what items are recyclable and what are not. This reduces confusion and lowers the effort required to recycle correctly. Social influence is another useful approach outside of gamification. Some apps include community leaderboards or let users share progress on social media. These features use peer motivation, as users feel encouraged when they can compare their actions with others.

Feedback and progress tracking are important for keeping users engaged. When people see how much they have recycled, they feel a sense of progress. Notifications about milestones can also give them a feeling of achievement. This kind of positive reinforcement encourages users to continue and build consistent recycling habits.

A case study conducted by Pamungkas et al. [13] compared a basic mobile app with a gamified one to see how gamification affects engagement. Both versions were found useful and easy to use. However, the gamified version led to higher engagement. Users of the gamified app logged activities more often and felt more focused. They also showed stronger involvement overall. Features like earning points and tracking progress helped increase interest and supported long-term motivation.

These findings show that gamification can improve user engagement. Using similar elements in recycling apps may increase motivation. It can also support users in building consistent and long-term recycling habits.

2.2. Existing Recycling Applications

In recent years, mobile applications have played an important role in encouraging recycling. They provide convenience, rewards, and educational tools to the public. In Malaysia, several apps have been developed to promote sustainable waste management. Examples include Recircle, KITARecycle, EcoScan, and iKarangguni. Each of these applications uses a different approach to motivate recycling behaviour. Each app takes a different approach to motivate users, but many still face challenges that limit their ability to support long-term recycling behaviour.

Recircle is a mobile application designed to make recycling easier by offering users both cash and point-based rewards [14]. Through the app, users can monitor their carbon footprint, upload photos of recyclable items, and schedule on-demand pickups. There's also a donation feature that lets users contribute their earned points to charity. However, the app's pickup service is only available in certain areas, which limits its accessibility. Users outside of the covered zones may find it harder to participate, reducing the overall reach and effectiveness of the platform.

KITARecycle, an initiative by SWM Environment, offers users Recycling Points (RP) in exchange for over 30 different types of recyclable materials [15]. The app provides features such as collection schedules, recycling cage locations, and point redemption for cash rewards. Although the platform has successfully increased recycling awareness in certain regions, it primarily operates in southern Malaysia, limiting its accessibility and impact for users in other parts of the country.

EcoScan simplifies waste sorting using photo and barcode recognition technology [16]. Users can scan items to receive specific sorting advice and participate in litter collection challenges to earn EcoCoins, which are redeemable for eco-friendly products. While EcoScan promotes proper waste disposal and environmental awareness, its educational content remains limited to sorting guidance, without broader information on sustainable recycling practices or environmental impact.

iKarangguni enables users to track their recycling contributions and earnings in real time [17]. The application also provides information on upcoming recycling events to encourage community involvement. However, users are required to contact collectors via external platforms, such as WhatsApp, to arrange pickups, adding complexity and reducing convenience in the recycling process.

2.3. Summary of Finding

Although these applications incorporate various incentive mechanisms and convenience features, they still present significant limitations in terms of accessibility, personalised engagement, and sustained motivation. Furthermore, many of these applications do not offer a well-rounded combination of educational content, real-time access to nearby recycling centres, and gamified elements that could help boost user engagement and support lasting behavioural change.

As shown in Table 1, each of the existing recycling applications includes specific features designed to promote user participation. However, common limitations remain, such as limited-service coverage, the absence of comprehensive educational materials, and minimal implementation of gamification. To address these gaps, the proposed Recycle Tracker Application incorporates several key features, including real-time mapping of recycling centre locations, step-by-step DIY recycling guides, and engaging gamified elements such as the Dino Evolution system and eco-challenges aimed at promoting long-term participation.

3. SYSTEM DESIGN

The Recycle Tracker Application was designed primarily to promote sustainable recycling habits through gamification mechanisms. While the system includes common features such as login, map access, and educational guides, the design emphasis is on features that directly contribute to user motivation and long-term engagement.

Figure 1 illustrates the use case diagram of the application, which highlights the interactions between users and the system. Among these, several features form the core of the gamification mechanism. The recycling record function allows users to log their activities. Each submission adds eco-points, which act as the app's reward currency. The goal-setting function strengthens this system. Users who achieve their self-defined goals earn extra eco-points. This

process helps to build long-term behavioural change. The eco-challenge feature adds an interactive element. Users can join or create challenges, and their progress is shown on leaderboards. This fosters accountability and healthy competition. The Dino Evolution system gives visual feedback. Accumulated eco-points help a virtual dinosaur grow. This creates an emotional connection and a sense of achievement.

Table 1. Comparison of Existing Recycling Applications and the Proposed Application

Feature	Recircle [14]	KITARecycle [15]	EcoScan [16]	iKarangguni [17]	Proposed Application (Recycle Tracker)
Rewards/Incentives	Cash, points, donation	Recycling Points (RP)	EcoCoins, product rewards	Cash-based rewards	Dino Evolution, eco-challenges
Recycling Centre Accessibility	Limited pickup locations	Operates in southern Malaysia	Nationwide (sorting advice only)	Requires WhatsApp for pickups	Nationwide, real-time map of recycling centres
Educational Resources	Carbon footprint tracking	Limited to news articles	Sorting guidance only	Limited event information	DIY recycling guides, sorting tips
Gamification	Basic points and donation	Points only	Litter collection challenges	Basic financial reward system	Comprehensive gamification (Dino Evolution system, eco-challenges)
User Convenience	Photo uploads, arranged pickups	Collection schedules, cage locations	Item scanning, sorting advice	Real-time tracking, manual arrangement	Real-time progress tracking, location map

Other supporting features include recycling guides, DIY tips, and a real-time map of recycling centres. These features improve usability and make knowledge more accessible. However, they function only as secondary enablers. The main driver is still the gamification framework. This framework is built on eco-points, challenges, goals, and Dino Evolution. It remains the core mechanism that encourages and sustains recycling behaviour.

4. IMPLEMENTATION

4.1. Development Tools and Environment

The Recycle Tracker Application was built with the Flutter framework. This choice allows cross-platform compatibility with both Android and iOS devices. Firebase was used as the backend platform. It manages user authentication, real-time database operations, and cloud storage. For image handling, Cloudinary was integrated. It supports user profile pictures and Dino Evolution visuals with efficient media management. These technologies were selected for their scalability and seamless integration. They also provide strong support for real-time data handling, which matches the core requirements of the project.

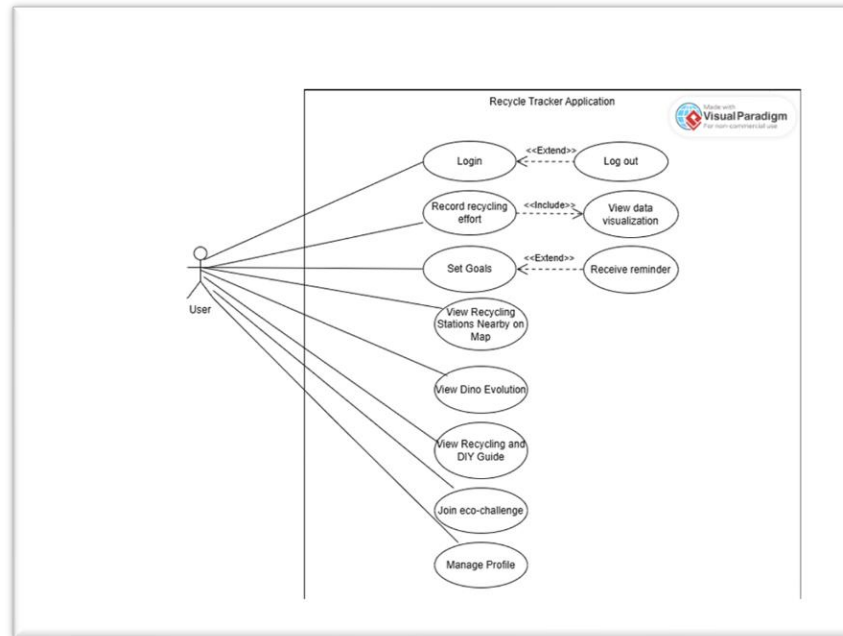


Figure 1. Use Case Diagram

4.2. Gamification Mechanism

The Recycle Tracker Application uses a gamification framework to make recycling engaging and rewarding. This approach helps to address barriers found in the preliminary survey. These barriers include lack of motivation, limited recycling knowledge, and accessibility challenges. The application integrates points, progression, and social recognition. These elements encourage users to take part in eco-friendly activities on a consistent basis.

Users earn eco-points by completing different activities in the application. The Eco-Challenge feature gives points for finishing assigned recycling tasks. This provides immediate feedback and reinforces positive behaviour. The Goal Setting feature lets users create personal recycling objectives. Points are awarded when these goals are achieved, which supports habit formation. The Recycling Effort feature allows users to record their activities. Each record adds to their accumulated points and builds a sense of accomplishment. The DIY Guide serves only an educational purpose. It offers tutorials and knowledge but does not award points. The Interactive Map helps users locate recycling stations. Points are only given when users discover and submit new stations that are approved.

Accumulated eco-points influence the leaderboard ranking. However, only points earned from Eco-Challenge tasks count toward this social ranking. Points from all eligible activities contribute to Dino Evolution. This virtual pet system visually represents a user's environmental impact. Users can track their progress through points, leaderboard positions, and Dino Evolution growth. These elements reinforce engagement and create a sense of accomplishment.

The gamification process works as a continuous behavioural cycle as shown in Figure 2. Users start by completing tasks. These tasks include joining Eco-Challenges, setting and achieving goals, recording recycling efforts, submitting new stations for approval, or using the DIY Guide for knowledge. Eligible tasks reward users with eco-points and visual feedback. Points from Eco-Challenges appear on the leaderboard. Points from all eligible tasks contribute to Dino Evolution. Users receive recognition through their points, leaderboard ranking when applicable, and Dino Evolution growth. This feedback creates positive reinforcement. Positive reinforcement increases motivation and engagement. Over time, repeated participation helps users build sustainable recycling habits. The cycle loops continuously, promoting long-term behavioural change and ongoing commitment to recycling.

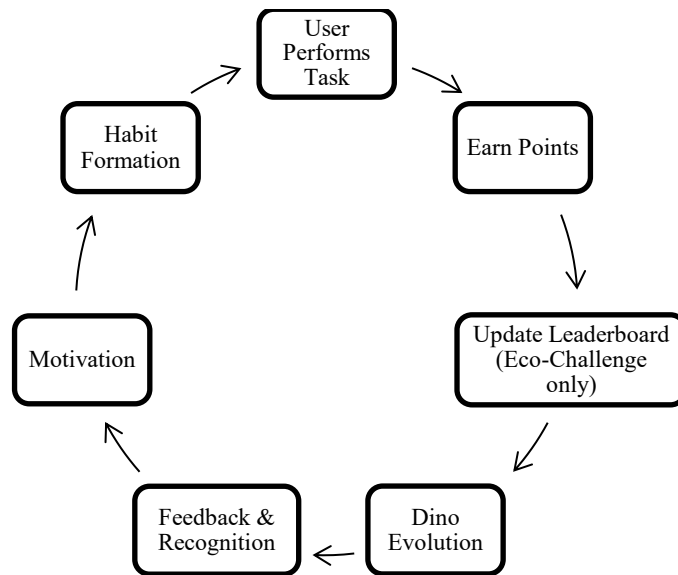


Figure 2. Gamification Process Diagram

4.3. Dino Evolution Implementation

The Dino Evolution feature is a central component of the application's gamification strategy, designed to visually represent and reward users' eco-friendly actions. Positioned prominently on the home page, it displays the user's virtual pet dinosaur along with the accumulated eco-points, as shown in Figure 3(a).

As shown in Figure 3(b), users can customise their dinosaur's name by tapping the edit icon, enhancing personalisation and emotional attachment to the virtual pet.

Whenever a user reaches a new evolution threshold, the application automatically detects the change and displays a congratulatory pop-up the next time they access the home page (Figure 3(c)). This pop-up informs users of their Dino's growth and reinforces motivation through positive feedback.

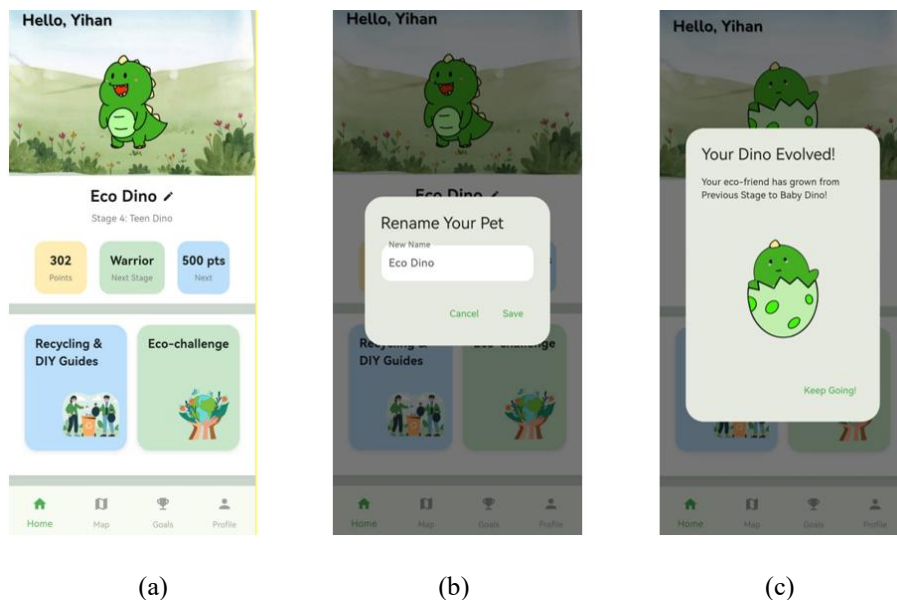


Figure 3. Dino Evolution Screen

As users engage with the application by performing sustainable actions, they earn eco-points that contribute directly to the evolution of their dinosaur. The breakdown of eco-point awarding activities is summarised in Table 2.

Table 2. Methods of Earning Eco-Points in the Application

Action	Eco-Points Awarded
Recording a recycling effort (daily limit)	Up to 2 points
Successfully completing a recycling goal	10 points
Daily eco-challenge check-in	2 points
Eco-challenge photo reported (successful)	2 points
Eco-challenge ranking: 1st place	50 points
Eco-challenge ranking: 2nd place	30 points
Eco-challenge ranking: 3rd place	20 points
Adding a new recycling station (admin approved)	20 points

The dinosaur progresses through distinct stages based on the total eco-points accumulated, as summarised in Table 3. Users begin at the Egg stage and evolve through Cracked Egg, Baby Dino, and Teen Dino as they earn more eco-points. Upon reaching 500 eco-points or above, users unlock the final evolution stage, Eco Dino Warrior, which represents mastery in the application and recognizes consistent engagement in environmentally sustainable activities.

Table 3. Dino Evolution Stages Based on Eco-Points

Stage Name	Required Eco-Points
Egg	0 – 49
Cracked Egg	50 – 149
Baby Dino	150 – 299
Teen Dino	300 – 499
Eco Dino Warrior	>500

By combining visual progression, personalised interaction, and an eco-points reward system, the Dino Evolution feature fosters long-term user engagement and encourages consistent participation in sustainable behaviours.

4.4. Recycling and DIY Guide Implementation

The Recycling and DIY Guide provides users with educational content on correct waste sorting and creative upcycling practices. While not part of the gamification mechanism, this feature complements the application by reinforcing sustainable behaviour through knowledge sharing. Figure 4 shows the interface of the guide, which serves as a supplementary tool to support user awareness rather than a gamification element.

4.5. Join Eco-Challenge Implementation

The Eco-Challenge feature motivates users to adopt sustainable habits by transforming environmental actions into interactive competitions. As illustrated in Figure 5, users can browse a list of available challenges and choose to either create new ones or join existing ones using invitation codes. This design makes participation simple and accessible, while also ensuring that every challenge directly links to the application's gamification system, where user engagement is rewarded with eco-points and contributes to long-term motivation.



Figure 4. Recycling and DIY Guides Screen

Whether public or private, challenges provide flexible participation opportunities. Public challenges encourage large-scale engagement, where users participate through daily check-ins by uploading photos of eco-friendly activities as proof of completion. Each valid check-in in a public challenge earns eco-points, which contribute to both leaderboard rankings and Dino Evolution progress. Private challenges, on the other hand, support smaller group dynamics interactions through invitation codes, as shown in Figure 5(b) and Figure 5(c). Although participants in private challenges also complete activities through the same check-in process, these check-ins do not award eco-points and therefore do not contribute to Dino Evolution progress. Instead, private challenge check-ins are reflected only in the leaderboard, allowing users to remain motivated through friendly competition and peer comparison.

Once a challenge is joined, users gain access to a detailed participation view that highlights progress and rankings. As shown in Figure 6(a), each challenge displays its objectives, duration, and a visual tracker of ongoing progress. A built-in leaderboard provides real-time standings (Figure 6(b)), featuring podium visuals for the top three participants and a highlighted position for each individual user. This competitive mechanism strengthens extrinsic motivation by encouraging users to remain consistent with their sustainable actions.

User actions are recorded through a daily check-in system, where participants upload photos of eco-friendly actions as proof of engagement (Figure 6(c)). Each public challenges, each valid check-in awards eco-points that contribute to both leaderboard rankings and Dino Evolution growth. For private challenges, valid check-ins contribute only to leaderboard standings and do not award eco-points. By linking everyday sustainable actions with gamified rewards and social competition, the system reinforces long-term behavioural change and encourages the development of environmental responsible habits.

In addition to competition, the Eco-Challenge integrates a community dimension. As shown in Figure 7, user-submitted check-in photos are displayed in a shared gallery. This feature fosters transparency inspires participants through peer examples and reinforces a sense of collective achievement. Attribution details such as contributor name and submission date ensure authenticity, while visual storytelling motivates others to stay active.

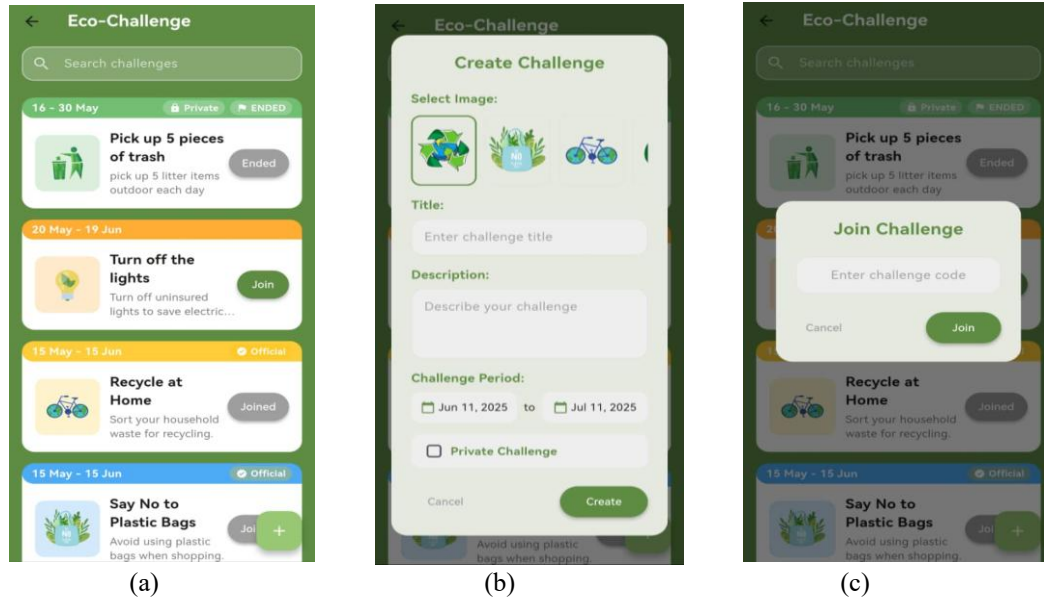


Figure 5. Eco-Challenge List Interface Screen

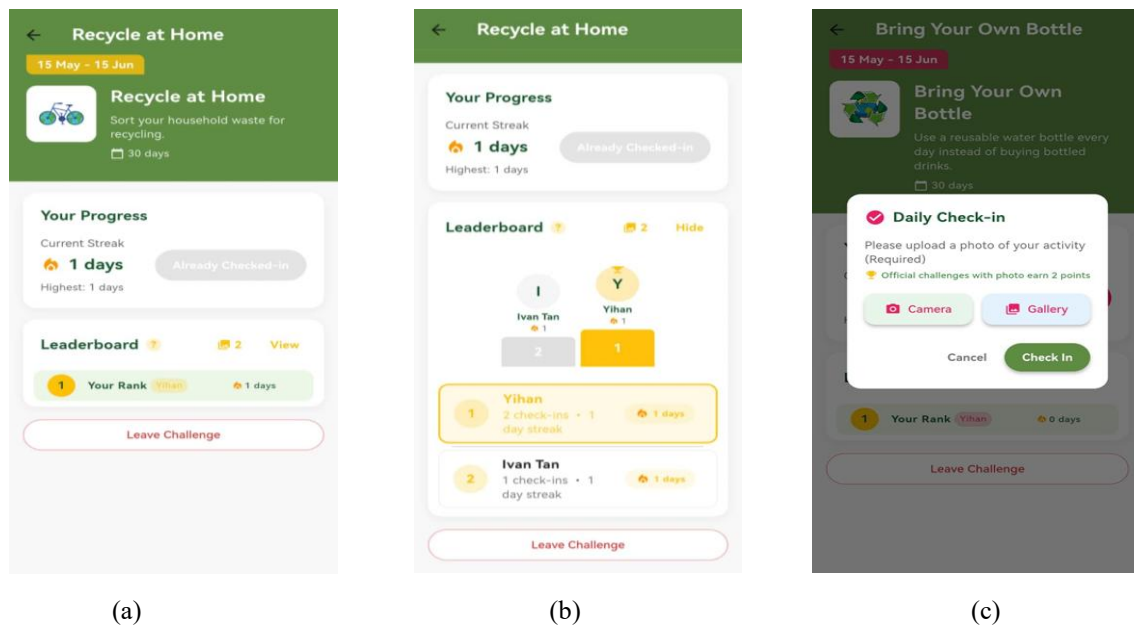


Figure 6. Challenge Participation Interface

By combining competition, accountability, and community recognition, the Eco-Challenge plays a central role in the gamification framework of the Recycle Tracker Application. It sustains engagement by linking eco-friendly behaviours to eco-points, leaderboard standings, and Dino Evolution progress, while also promoting a sense of shared responsibility within the community.

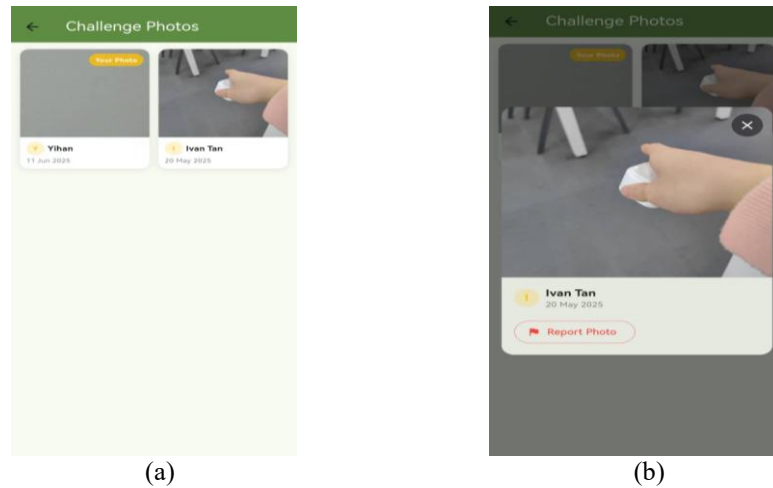


Figure 7. Challenge Photo Gallery Grid View

4.6. Recycling Station Nearby on Map Implementation

The application integrates a real-time map feature that enables users to locate nearby recycling facilities and contribute to sustainable waste management. This feature improves accessibility and connects to the gamification system. Users who submit new recycling stations receive eco-points once their submissions are verified by administrators. These points contribute to the Dino Evolution system. The process ensures that community contributions are recognised and reinforced through gamified progression. Figure 8 shows the map interface, which highlights this additional functionality.

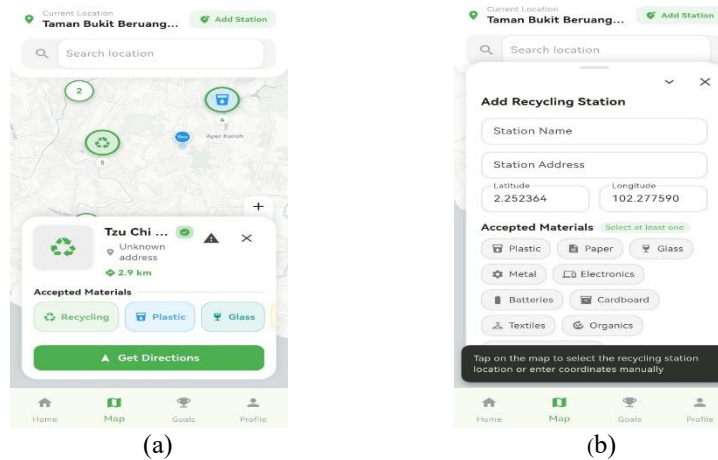


Figure 8. Map Interface

4.7. Set Goal Implementation

The goal-setting feature allows users to create and track personal sustainability goals. These goals may include reducing plastic use or recycling regularly. As shown in Figure 9, users can use a dashboard to manage their goals and monitor progress. Unlike traditional goal trackers, this feature is directly linked to the gamification framework of the application.

When users achieve their goals, they earn eco-points. These points directly contribute to the Dino Evolution system. The connection turns personal achievements into visible progress as the virtual dinosaur grows. This process helps to reinforce long-term motivation. Figure 9(a) shows the interface where users can view and track the status of their

ongoing goals. Users can create new goals through the interface, as shown in Figure 9(b). Once defined, these goals are linked to the eco-points system. Successful completion contributes to personal progress and enhances the overall gamified experience.

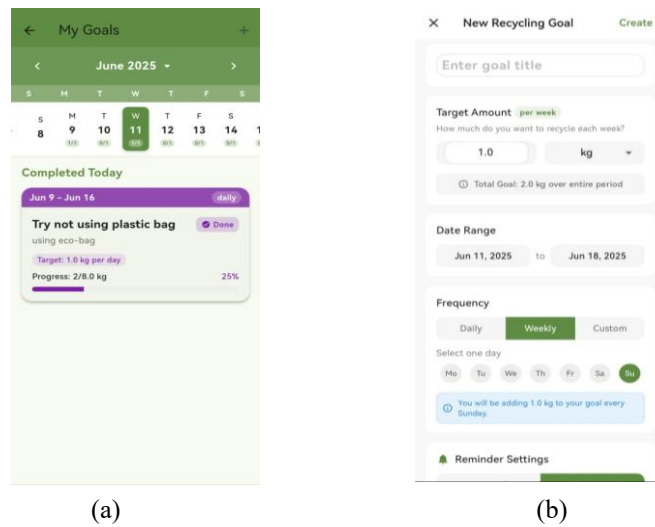


Figure 9. Set Goal Interface

This feature supports habit formation and provides meaningful feedback. It links individual actions with gamification outcomes. As shown in Figure 10, the detailed tracking interface allows users to review their performance. It also reinforces the connection between goal achievement, eco-points, and Dino Evolution.

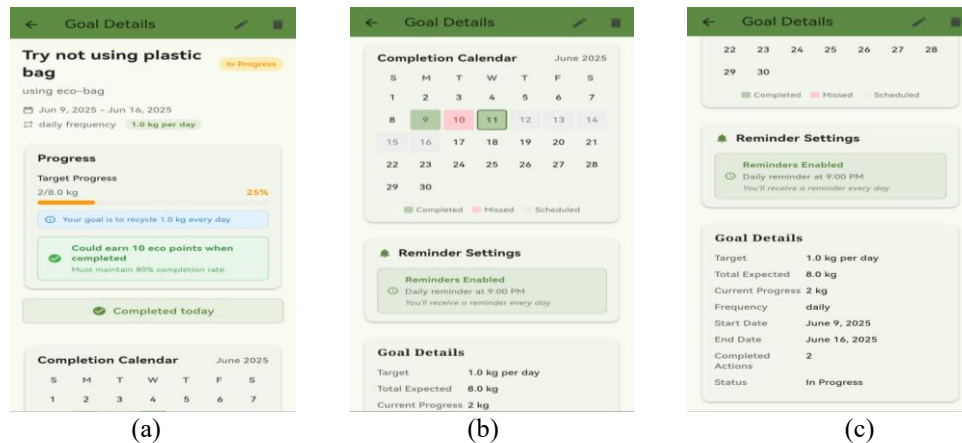


Figure 10. User Performance and Progress Tracking Interface

This screen displays goal period, frequency, and target details. It also provides progress indicators and visual analytics. A colour-coded completion calendar helps users recognise behaviour patterns. Reminder settings and performance metrics support transparency and encourage consistent engagement.

4.8. Record Recycling Effort Implementation

The feature of record recycling effort allows users to document their activities across different material categories. Each valid record contributes eco-points to the gamification framework. These points directly influence Dino

Evolution. This mechanism turns routine recycling actions into visible progress. It motivates users to stay consistent with their recycling habits.

As shown in Figure 11, the interface allows users to log their recycling efforts and review past submissions. Each valid record earns eco-points. A one-entry-per-day rule is applied to promote consistency rather than excessive entries. The interface gives immediate feedback on recycling activity and eco-points earned. This visible progress helps to reinforce user motivation.

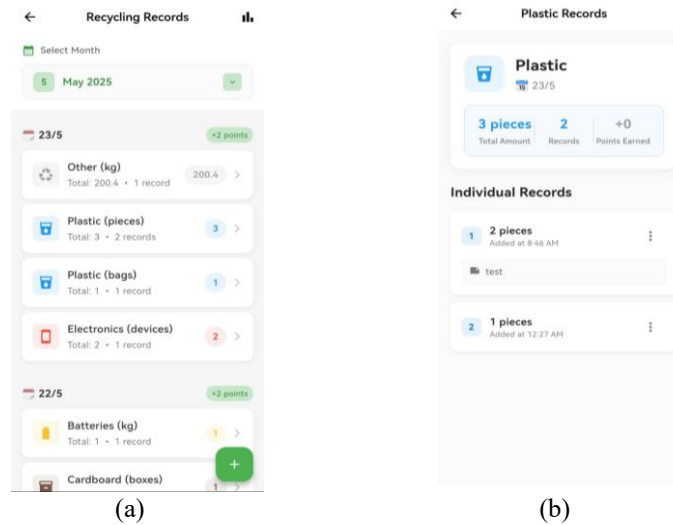


Figure 11. Recycling Record Screen

To strengthen engagement, the application includes a statistics view, as shown in Figure 12. Users can review their accumulated eco-points, recycling frequency, and material categories. This feature highlights individual contributions and reinforces the link between recorded actions, eco-points, and the growth of the Dino Evolution system.



Figure 12. Recycling Statistics Screen

As shown in Figure 13, users can submit new recycling records through a simple input form. Once confirmed, these records are converted into eco-points that not only acknowledge the user's effort but also advance their Dino Evolution stage. This integration of record keeping with gamification ensures that everyday recycling activities are consistently rewarded and visibly connected to behavioural outcomes.

Figure 13 consists of two panels, (a) and (b), showing the 'Add Recycling Record' form. Panel (a) is the main form with fields for Date (11/6/2025), Material Type (Choose material type), Unit (Select material first), and Amount. Panel (b) shows optional fields for photo upload, Notes, and a checklist for completing the record.

Figure 13. Recycling Record Creation Form

5. ANALYSIS AND DISCUSSION

To evaluate the usability and functionality of the Recycle Tracker Application, a structured user study was carried out with 30 participants. Each participant interacted with the app under typical usage scenarios and then completed a post-session questionnaire. The evaluation included a mix of Likert-scale questions to measure usability, binary (yes/no) questions to validate core functionalities, and an optional section for open-ended feedback. These metrics were selected because Likert-scale ratings provide quantitative insights into usability, binary responses directly confirm functional correctness, and open-ended feedback captures qualitative perspectives, offering a more holistic evaluation of the application. The usability results, summarized in Table 4, showed that users consistently gave high ratings for the app's interface clarity, ease of accessing features, and its ability to motivate recycling behaviour. Functionality testing confirmed a 100% success rate across all key modules, including user login, map-based station searches, goal setting, recycling effort logging, and gamification progress tracking. The testing was conducted by having participants perform representative tasks such as logging in, locating a recycling station on the map, setting a goal, recording a recycling effort, and checking gamification progress. Each task was considered successful if it could be completed without system errors and the expected output was produced. Across all participants, every task was completed successfully, indicating that the app's core modules functioned reliably under typical usage conditions. These findings suggest that the application is not only technically reliable but also meets user expectations and effectively supports the behavioural goals of the project.

The sample size of 30 participants is consistent with recommendations in usability research. Nielsen's principle suggests that a relatively small number of users (around 5 per round of testing) is already sufficient to uncover most usability issues, and many early-stage evaluations of mobile applications adopt 20–30 participants [18]. Therefore, a sample of 30 was deemed adequate for this study, as the aim was usability and functionality testing rather than large-scale statistical analysis.

In addition, user engagement and motivation to recycle were assessed through qualitative feedback and interaction with the app's gamification features. Engagement was reflected in how participants responded to elements such as

Dino evolution progress, Eco-Challenge activities, and leaderboard participation. Motivation was primarily captured in open-ended feedback, where several users mentioned that the gamification features made the application more enjoyable and encouraged them to continue recycling. The detailed results of the survey and user responses are presented in Table 4.

Table 4. Summary of Usability and Functionality Test Results

Feature Evaluated	Test Result (Positive Response Rate)
Interface Clarity & Navigation	100% (70% Strongly Agree, 30% Agree)
Clarity of Recycling/DIY Content	96.7% (60% Strongly Agree, 36.7% Agree)
Engagement from Dino Evolution	93.4% (66.7% Strongly Agree, 26.7% Agree)
Ease of Locating Stations via Map	100% (66.7% Strongly Agree, 33.3% Agree)
Ease of Joining Eco-Challenges	100% (70% Strongly Agree, 30% Agree)
Increased Motivation to Recycle	96.7% (66.7% Strongly Agree, 30% Agree)
Login and Registration Success	100% Yes
Access to Recycling & DIY Guides	100% Yes
Accuracy of Nearby Recycling Station Display	100% Yes
Success in Setting Personal Goals	100% Yes
Success in Recording Recycling Efforts	100% Yes
Accuracy of Dino Evolution Progress Updates	100% Yes

6. CONCLUSION

The proposed Recycle Tracker Application was developed to support recycling participation and promote sustainable habits through mobile technology. It allows users to find nearby recycling centres through real-time map integration. Users can set and track personal environmental goals. They can also access educational content, including recycling tips and DIY upcycling guides.

One of the key features of the application is its use of gamification. The Dino Evolution system and Eco-Challenges play a central role in this design. These elements reward users with eco-points and leaderboard placements. They make the experience more engaging and motivating.

The evaluation conducted with 30 participants indicated that the application was generally well received by the participants. The tested core functions operated successfully under the evaluated conditions, including recycling centre discovery, goal tracking, and gamified engagement features. The findings suggest that the application has the potential to support recycling-related activities and promote user engagement in sustainable practices. While the app has achieved an encouraging result, there are still areas that could be improved. Currently, updates for new recycling stations depend on manual reporting, which could be enhanced through automation or community-based verification to improve accuracy. Additionally, while the application offers cross-platform compatibility for Android and iOS, future work could explore expanding web-based access to reach a wider audience.

In future development, features such as AI-driven waste recognition [19], chat bot with translation [20] and integration with external recycling programmes or government initiatives can be considered to increase real-world impact. By continuing to refine and expand its features, the Recycle Tracker Application has the potential to play a significant role in supporting Malaysia's transition towards a more circular, environmentally conscious economy.

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AUTHOR CONTRIBUTIONS

Yi Han Ng: Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Validation, Visualization, Writing – Original Draft Preparation;

Pey Yun Goh: Conceptualization, Project Administration, Resources, Supervision, Writing – Review & Editing;

Lee Yeng Ong: Review & Editing;

Kian Ming Lim: Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

The code developed for this research is original and authored by the contributors of this publication. It is protected under copyright [LY2025W11005] by the authors and may be made available upon reasonable request for academic and research purposes.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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