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Article

Rewarding Sustainability: A Gamified Mobile Application for Urban Organic Waste Composting

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Abstract: Environmental Education is increasingly gaining importance on the global stage, given the need to preserve suitable conditions to ensure biodiversity, as well as the survival of future generations of human beings. Related to this issue is the management of urban organic solid waste. Urban solid waste is an environmental concern due to the various problems it causes to the environment. Thus, based on the above context, the main objective of this research is to develop a mobile application that facilitates exchanges and rewards aimed at stimulating the composting of organic solid waste, using gamification strategies. Ultimately, the project aims to stimulate better management of the generated organic waste, enabling the exchange of points obtained for rewards in partner companies, enhancing the process of environmental education and encouraging participation in waste recycling.

Keywords: environmental education; solid waste recycling; gamification.

1. Introduction

Urban solid waste is an environmental concern due to the various problems it causes. According to the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE), in 2022, 81.8 million tons of Municipal Solid Waste (MSW) were generated in Brazil. Of this total, 5.7 million tons were not collected and were improperly disposed of (ABRELPE, 2022). Of the approximately 76.1 million tons of MSW collected, only 61% were disposed of in sanitary landfills, while the remainder was directed to dumps and controlled landfills, constituting a serious environmental, social, and economic problem. Regarding the composition of MSW, the organic fraction remains its main component (45.3%), with an average disposal of 170 kg of organic matter per person each year [1].

Within this context, composting organic waste presents a sustainable alternative, potentially reducing the fees paid by public authorities for transportation and disposal in

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sanitary landfills. Additionally, greenhouse gases (GHG) are produced in large volumes in sanitary landfills due to the degradation of organic matter under anaerobic conditions, a problem that can be minimized through composting [2]. GHG are also generated in the production and use of chemical fertilizers [3], which can be reduced by using fertilizer produced from composting. This factor may also lower agricultural production costs [3]. Considering these issues, this study presents an application aimed at promoting better management of organic waste. It should be noted that this research is part of a larger project titled "Connecting Science, Innovation, and Artificial Intelligence: Building a Smart City Model to Mitigate Environmental Impacts Through Organic Waste Composting," funded by FAPERJ - Carlos Chagas Filho Foundation for Research Support in the State of Rio de Janeiro. The project involves representative stakeholders with diverse and complementary profiles, including: Rio de Janeiro State University (UERJ) (Graduate Program in Computational Modeling – Polytechnic Institute); Fluminense Federal University (UFF) (Professional Master's Program in Production Engineering and Computational Systems, UFF Innovation Agency, Department of Computer Science RCM); Veiga de Almeida University (UVA) (Professional Master's Program in Environmental Sciences - PMPCMA); Brazilian Agricultural Research Corporation (EMBRAPA) (Embrapa Soils and Embrapa Agrobiology); Companies VM9 Information Technology Ltd., OrganoKits Sustainable Practices Ltd., and Reciclotron and Municipal Government of Nova Friburgo (PMNF).

The project will be implemented in the city of Nova Friburgo, in the state of Rio de Janeiro, Brazil.

2. The Application – SigCol App

The application—named SigCol—aims to support educational processes related to environmental education, particularly in raising awareness about the importance of recycling. It incorporates gamification concepts and game design elements to stimulate interest and engagement with environmental issues. However, the objective is not for users to perceive it merely as a game or compete for status, but rather to promote behavioral change. It should be noted that the app is not simply a game but an integration of gaming and reward systems, following the guidance of previous studies [4-6].

The development of this game to support environmental education and urban solid waste recycling can be considered applied research with qualitative and quantitative characteristics. Applied research seeks to utilize scientific knowledge to solve practical problems or develop solutions. In this case, the focus is on creating a concrete product (a game). Its relevance lies in addressing real-world issues, with the goal of improving processes, products, or services. Quantitative research aims to assess user perceptions of the game’s usability, while mixed-methods research will be applied post-implementation. The former seeks to collect data on the game’s effectiveness in increasing recycling knowledge, while the latter evaluates user satisfaction and measures behavioral change impact. The development

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process involves qualitative research (understanding user needs) and quantitative research (assessing the game's impact). Furthermore, this applied research seeks to create a practical solution for environmental education and urban solid waste recycling.

The increasing use of games in non-entertainment contexts, known as Serious Games (SGs), along with gamification (applying game mechanics, dynamics, and technologies for learning or behavioral change), is transforming daily life by introducing engagement in routine activities [7, 8]. The use of SGs and gamification techniques has gained prominence in recent years for developing game-based frameworks for purposes beyond leisure or entertainment. The application of games for training and behavioral change is not new (e.g., military training simulations) [9]. Game-based learning in training and behavioral change applications has expanded with the rise of mobile technology in recent years [10].

Another key aspect of this research is the reward system. A reward is an objective way to describe the positive value an individual assign to an object, behavioral act, or internal physical state. Primary rewards include those necessary for species survival, such as food [11]. Gamification, as commonly applied, operates by establishing reward structures and regular feedback mechanisms similar to those found in games, aiming to motivate specific behaviors. Rewards such as points, levels, badges, missions, and leaderboards are often combined with visual feedback to encourage repeated engagement. These techniques have proven effective in motivating users to open an app more frequently, spend more time using it, or increase participation levels [12].

3. Reward Systems in Games: Theoretical Framework

The use of point systems is among the primary motivational elements, and this is the foundation of the developed app. Points can be used to reward users across multiple dimensions, categorized into different types. They may serve as status indicators, allowing users to unlock content or redeem them for rewards [6]. According to the same authors, redeemable points can be exchanged by players and are commonly used in social games and loyalty programs. These bonuses provide benefits once a certain threshold is reached and typically have an expiration date.

The reward model adopted in this research combines Collectible Rewards with Fixed Rewards, as defined by [11]. The system operates as follows: users request weekly or monthly waste collection at their residence, accumulating points in the process. Upon reaching a specific point threshold, they gain access to a quiz, where correct answers yield additional points. Once a predefined threshold is met, users can exchange points for products or services available in the reward catalog.

This strategy aligns with the framework proposed by Nah et al. [13], who argue that gamification follows a flow structured around five key pillars:

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Goal Orientation – The principle that objectives can be segmented into long-term, medium-term, and short-term goals. For instance, a long-term objective may be divided into medium-term sub-goals, which are further broken down into short-term tasks (e.g., completing a level). Well-defined objectives help sustain user motivation and engagement, with difficulty scaling progressively as the player advances, ensuring systematic and continuous learning.

Achievements – Recognition of player accomplishments enhances gratification, thereby increasing motivation and engagement. A trophy system for significant in-game milestones exemplifies how this tool can be applied in educational games to improve learning retention.

Reinforcement – In educational contexts, reinforcement is critical, as behavioral learning theory posits that knowledge acquisition occurs through feedback mechanisms. The quiz system implemented in this study exemplifies this approach: correct answers trigger a green confirmation message and virtual in-app currency (positive reinforcement), while incorrect responses provide corrective feedback, equipping the user with additional information for future attempts.

Competition – Within educational settings, competition plays a significant role in sustaining engagement. Certain player profiles exhibit higher motivation when competing against others. Clear competition rules must be established to foster a sense of control.

Fun Orientation – A necessary component to encourage user participation. "Fun is a fundamental requirement in most games. Thus, for an educational game to effectively motivate and engage learners, incorporating enjoyable elements is essential."

4. Agile Methodology for Mobile Game Development

To efficiently develop a mobile game, an agile methodology was adopted. This approach enables continuous adaptation, collaboration, and incremental delivery [14]. The following steps were implemented:

a) Context Understanding – Analysis of the game's objectives, target audience, and requirements.
b) Feature Identification – Key functionalities and resources were defined.
c) Team Formation – A cross-functional team was assembled.
d) Product Backlog Definition – All required functionalities and tasks were listed and prioritized based on user value and complexity.
e) Sprint Execution – Development was divided into short iterations (1-4 weeks), each with a clear objective.
f) Sprint Planning – Backlog items were selected for implementation in each sprint.
g) Development and Testing – Continuous testing ensured quality control.

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h) Weekly Meetings – Progress updates, obstacle identification, and collaborative problem-solving.
i) Demonstration – Completed functionalities were reviewed.
j) Process Evaluation – Iterative refinements were made based on feedback.

4.1 Results

Navigation and Interface Design

Global navigation was implemented to enhance usability, allowing users to access different sections of the app efficiently. This design minimizes the need for excessive screen transitions.

The initial user registration page with basic information is shown in Figure 1. Figure 2 displays the user and application information, such as the terms of use, the about developers tab, the ranking showing this user's position relative to other users in terms of score, leading to peer competition. Also available is a tab with the collection history made, a tab for the Quiz with questions related to environmental education, and a shop where users can exchange their points for different rewards.

The QR code in Figure 3 serves so that the worker responsible for collection at the user's residence can read this code and automatically enter the collected weight data directly into the user's account.

Figure 4 shows the result of the Quiz, that is, how many points this user received as a reward for answering environmental education questions correctly. There are four levels of questions, easy, medium, difficult, and extreme. The more difficult the question, the more points are received for a correct answer. In this way, more advanced players can be rewarded more appropriately, while players who are beginners in the topic of environmental awareness can choose easier questions, while learning about the subject, having more chances to answer correctly and ensure their score, even if reduced. Figure 4 shows that the user selected the easy level.

The application also features a plant-based game module, which operates as follows: upon entering the game screen, the user is presented with a seedling, that is, a plant in its initial growth stage. The user must then establish a routine of accessing the game daily, obtaining a watering can locate at the top right corner of the screen (Figure 5), and watering the plant to facilitate its growth. To prevent the user from accessing the game multiple times a day and thereby artificially manipulating the game's intended pace, a timer is implemented to regulate the game's duration, ensuring the watering can be not available for reuse on the same day. Once the plant reaches full maturity, which takes approximately 5 days, the plant can be harvested and the user will receive points in return. The objective of this game is to encourage user engagement, not only with the plant game but also in relation to recycling and the environmental education content provided in the Quiz.

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Figure 1: presents the initial user registration screen with basic information fields.



Figure 2: shows the initial screen



Figure 3: Quiz screen

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Figure 4: Quiz Results Screen



Figure 5: plant-based game module

Figure 6 displays the reward store interface where users can exchange accumulated points. It should be noted that the images shown are illustrative examples only. Partner companies participating in the point redemption system have been anonymized in this representation. The available rewards include, but are not limited to: restaurant discounts, beauty products, and personal care services.

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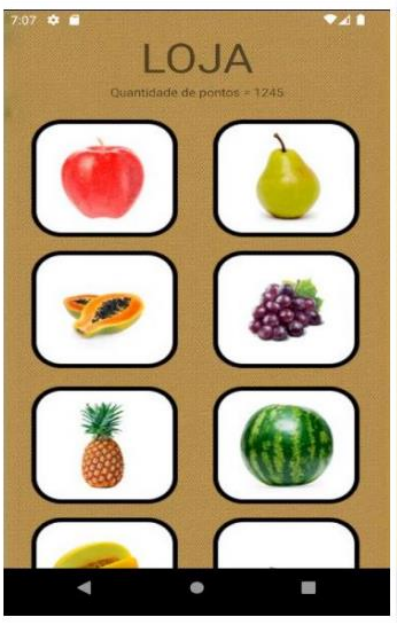


Figure 6: reward store interface

5. Discussion

The main goal of this study was to develop an application that facilitates exchanges and rewards through the recycling of solid waste, employing gamification strategies. The application is designed to stimulate better management of organic waste generated, enabling the exchange of points earned for rewards from partner companies, potentially enhancing the process of environmental education and encouraging participation in waste recycling. The system initiates when the user registers on the app and begins to use the system for the collection of domestic organic solid waste. Waste is collected in standardized containers, each container having a specific volume that can be selected based on the client's specifications. A QR code is placed on each container to uniquely identify this customer (user). The domestic collection can be conducted on a weekly or monthly basis (also in accordance with the client's request). The person who carries out the container collection, scans the QR code and thus enters the collected volume and this customer's data into the database. These data are stored in a historical table and points are calculated based on the number of collections performed. At each level reached, the customer will be able to exchange their points for products and/or services at partner companies. A Quiz with questions about recycling and environmental education is released so that the customer can respond and earn additional points for correct answers. The customer can also track their performance ranking among all participants in the system. Furthermore, the system includes a plant game that encourages user engagement.

To the best of our knowledge, as of the conclusion of this research, there exists no system with similar characteristics aimed at encouraging better management of solid organic

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waste in households of the city of Nova Friburgo or even in Brazil. It is also highlighted that the platform, of which the game is only a part, is still in the phase of integrating different modules, where the game is just one among them. Moreover, since the application is in its initial phase of implementation and use by users, results related to satisfaction with the game and the impact on user behavior change have not yet been obtained, work planned for the near future.

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Conflicts of Interest: The authors declare no conflict of interest.

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