

Eco Tetris: A Serious game on Sustainability

Paula Escudeiro, Márcia Campos Gouveia and Nuno Escudeiro

Games, Interaction and Learning Technologies, Instituto Superior de Engenharia do Porto, Porto, Portugal

pmo@isep.ipp.pt

magia@isep.ipp.pt

nfe@isep.ipp.pt

Abstract: Recycling has grown to be extremely relevant for the maintenance of our planet, but also for our well-being. Sustainability is a key issue in modern societies, relying on intergenerational care and education to promote recycling habits and social responsibility. Raising awareness towards recycling and healthy environmental habits, and motivating people to become more responsible about sustainability and the environment might be achieved through a game, designed to be simple and intuitive and to enhance the learning process. Eco Tetris is a game, designed to teach about the importance of recycling. Based on the well-known Tetris game, Eco Tetris builds upon this by adding card collecting mechanics and integrating the game with the real world via geo-referencing, beacons, and augmented reality experiences. The main goal of this game is to raise awareness and make the players more conscious of their environmental decisions and habits, while also being entertained. Our primary focus is the older generation, for whom the game is kept simple, in terms of both usability and design. Eco Tetris is a game whose main concern is to transmit knowledge on how to recycle and its importance for our planet. In this game, players are challenged to place the garbage in the right recycling bin. The mechanic is virtually the same as when recycling. Our goal is to imbue the player with recycling habits. The core gameplay loop will have the player doing the sorting exercise – separating garbage in-game, mentally associating it to its right colors. The bridge between the in-game and real-world is achieved via geo-reference modules and beacons. When visiting an eco-point, the player will have access to additional content, like an augmented reality experience, that provides positive reinforcement and knowledge about players' actions and the environment in general. We expect this game to promote ecological responsibility and a major view of one's role in the recycling process. The game is developed towards the enhancement of decision-making, memory skills, awareness, responsibility, and learning of its players.

Keywords: Serious game; Sustainability; Learning process; Usability; Beacons

1. Introduction

In the long term, a limited climate impact and sustainable development are of extreme importance for the planet. To better achieve it, the increase of a sense of social and global responsibility is a major concern of public policies and political goals.

When thinking of sustainable development, there should be a consideration for the maintenance of a green environment, better quality of life, and wellbeing. Thus, sustainability can be seen as a combination of environment preservation, protection, and stability. It also relies on a series of practices, habits, and behaviors, both individually and collectively, to reduce and minimize the destruction of our ecosystems (Koren, 2017).

Pro-environmental practices, habits, and behaviors must be continuous and enduring. In the context of environmental sustainability, the focus has shifted to understanding individual habits, such as recycling (Thomas & Sharp, 2013).

Recycling can be seen as an approach toward reducing waste disposal and limiting the climate change impact, while also being an approach to environmental preservation. The difference between recyclers and non-recyclers can be found in their beliefs, their social norms, their access to infrastructures and services of recycling, and their awareness and knowledge or lack of it (Thomas & Sharp, 2013).

For this reason, understanding information, knowledge, and education as key drivers of change, allows for a more deliberated solution. Motivating recycling is now more than just the government's responsibility. The normalization and increase of recycling habits must now be a concern of every individual, that understands the relationship between recycling and other important pro-environmental practices toward sustainable development (Thomas & Sharp, 2013).

Thus, our proposal is a serious game that raises awareness towards healthy environmental habits such as recycling, that aims to encourage people to become more conscious and responsible. Eco Tetris builds upon a

well-known game (Tetris), but, besides its entertainment purposes, it also focuses on educating the older generation about the need to protect and maintain the health of our planet.

Since the aim is to imbue the player with recycling habits, the core gameplay loop will have the player doing the sorting exercise. This means that the player will need to separate the garbage in-game and associate it with its recycling bins right colors. Color-coding systems are an important provider for interpreting encoded messages. When relying on text or audio is not possible, visual features can help people to access important information (Schloss, Lessard, Walmsley, & Foley, 2018). This is also an important part of the learning process since it creates a relationship between the virtual experience and the real-life world.

By raising awareness among the older generation towards recycling and sustainable development, it is expected that pro-environmental practices and intergenerational care increase at a micro level, fighting the concern of different countries and organizations of a possible irreversible climate emergency.

2. Recycling: an approach towards social responsibility and sustainability

Sustainability is a key issue in modern society, that has grown to be a waste society (Feo & De Gisi, 2010).

Waste could be considered the final product of a special production chain: wealth, consumption, waste. The wealthier the society, the greater the consumption; the greater the consumption, the more waste produced I

As such, “under modern waste management systems, a high priority has been placed on recycling of waste materials” (Salhofer & Isaac, 2002). However, in attempts to increase recycling, difficulties have arisen.

Globally, coming to terms with excessive waste pollution is critical for the aim of reaching the goals of sustainable resource management. This implies a need to increase recycling by individuals. However, this is easier said than done. Recycling at the household level is associated with costs (e.g., it is time-consuming) that incentivize individuals to avoid cooperation, i.e., adopting a free-rider behavior rather than choosing to recycle (Harring, Jagers, & Nilsson, 2019).

The inherent goal of recycling is to limit the impact of waste disposal. When choosing to adopt pro-environmental and sustainable behaviors such as recycling, the maintenance, and health of our planet are assured, as also our well-being. Misinformation or lack of it can inhibit these habits, making awareness necessary. By adopting an educational-based approach, it is possible to increase the engagement in the recycling process, the frequency of participation, and the number of recycled materials (Lane & Wagner, 2013).

But, when comparing access to information and pro-environmental habits, we notice that not always do people make their decisions based on knowledge and awareness (Feo & De Gisi, 2010). This relates to a non-significant relation between sustainable awareness and actual behavior (Cogut, Webster, Marans, & Callewaert, 2019).

In terms of creating awareness for environmental sustainability, two perspectives were identified concerning behavioral change. The first perspective assumes that changes in behavior are brought about by increasing public knowledge through raising awareness regarding an issue and by fostering an appropriate attitude. The second perspective proposes that individuals systematically review their choices and then act in their economic self-interest without the need to have enough knowledge and awareness in the first place (Hamid, Ijab, Sulaiman, Anwar, & Norman, 2017).

Thus, these pro-environmental attitudes, habits, or behaviors can be enhanced by engagement and awareness (Cogut, Webster, Marans, & Callewaert, 2019). Also, motivation can play an important role in increasing recycling habits, as well as technical infrastructure and orientation (Salhofer & Isaac, 2002).

[These are] the following requirements for environmentally oriented behavior: (1) There should be sufficient knowledge of the ecological context (the cognitive component) and a positive inclination towards ecological values. (2) The infrastructural prerequisites needed for environmentally oriented behavior (e.g., collection containers) must be available. (3) Environmentally friendly behavior must lead to positive results; therefore, incentives (possibly economic incentives) could be given (Salhofer & Isaac, 2002).

Adopting these pro-environmental habits, such as recycling, sustainable development, and the maintenance of our planet is made easier. Sustainability can be seen as stability, integrity and well-being, and health of humanity.

To promote this sustainability agenda and an enduring state, an integrated and proactive approach must be held individually and collectively (Ben-Eli, 2018).

Viewing sustainability as a system state—the result of the interaction of identifiable, specific variables—and anchoring the concept in the interaction of population and carrying capacity, leads to a more rigorous definition, [as follows]: (...) A dynamic equilibrium in the process of interaction between a population and the carrying capacity of its environment such that the population develops to express its full potential without producing irreversible adverse effects on the carrying capacity of the environment upon which it depends (Ben-Eli, 2018).

But, at this moment, the behavior of humanity is unsustainable, since people do not always participate in recycling even when infrastructures are provided (Thomas & Sharp, 2013).

As current consumer-driven behaviors and culture are inherently unsustainable, working toward changing behavior at the individual level is an essential component of being environmentally responsible citizens and working toward promoting a culture of sustainability. A culture of sustainability has been defined as: [. . .] a culture in which individuals are aware of major environmental (and social/economic) challenges, are behaving in sustainable ways, and are committed to a sustainable lifestyle for both the present and future (Cogut, Webster, Marans, & Callewaert, 2019).

Following the Millennium Development Goals, the 2030 Agenda for Sustainable Development of the United Nations highlights the importance of environmental sustainability, since it considers that our planet now faces an environmental and climate emergency (Arora & Mishra, 2019). For those reasons, solutions on a micro level such as raising awareness through an educative and serious game can support the agenda toward environmental sustainability (Arora & Mishra, 2019).

2.1 Serious games and sustainability

A mindset towards sustainability, pro-environmental habits and social responsibility relies on numerous and different approaches, such as serious games. These serious games, that intend to be educational, are an important tool for improving recycling habits, given that “While public awareness of climate change has grown over the years, many people still have misconceptions regarding effective individual environmental action” (Wang, et al., 2021).

Goals of serious games on sustainability could be summarized in (a) making players aware of the challenges associated with sustainability, (b) providing knowledge and understanding with the issue of sustainability, and (c) encouraging players to take actions and develop solutions that are environmental and socioeconomic balanced (Ouariachi, et al., 2018).

Considering the high potential digital games have on improving knowledge, literature identified the importance of a “sustainability mindset which enables individuals to engage in sustainable behaviours” (Fabricatore & López, 2011). Characteristics such as “domain-specific knowledge”, “reflective and critical thinking”, “systems thinking”, “sense of belonging to a living system” and “emotional commitment to sustainability” are found to be necessary to make people more aware and involved, more responsible and understanding, and more active and cooperative (Fabricatore & López, 2011). This is how digital games can help to educate on sustainability.

For instance, the creators of the serious game PEAR developed a game that has proven to improve “participants’ knowledge on sustainability and climate-change-related issues”. Their findings also demonstrate that this knowledge improvement result in pro-environmental attitudes. By using a game that is engaging, educational and immersive, behaviours change (Wang, et al., 2021).

In fact, the numbers are increasing. Over the last years, several digital games were developed thinking on sustainability. Games such as Keep Cool (“where players represent groups of countries that negotiate economic growth and climate change mitigation”), Climate Mission 3D (“where players learn how to reduce their carbon footprint as they play a series of mini-games”) and We Energy Game (“a serious game that aims to create awareness on the challenges in the provision of affordable energy from renewable sources for an entire town or city”) are found to be engaging and educational in terms of both sustainability and pro-environmental habits (Ouariachi, et al., 2018).

3. Methodology

Eco Tetris is a serious game on sustainability, social responsibility, and education. The project aims to develop an innovative concept for recycling, along with new technologies and automation strategies. The Eco Tetris methodology and the outcomes of the project will enhance knowledge and awareness, concern for the environment, and intergenerational care.

3.1 Concept

Eco Tetris is a game designed to teach about the importance of recycling. Eco Tetris is based on and built upon the well-known Tetris game, by adding card collecting mechanics and integrating the game with the real world via geo-referencing, beacons, and augmented reality experiences.

Eco Tetris aims to respond to the growing importance of sustainability, the planet's maintenance, and individuals' well-being. The idea is to raise awareness towards recycling and good environmental habits, by motivating people to become more responsible about ecology. The game should be simple and intuitive, created to consider older audiences.

The main goal of Eco Tetris is to spread awareness and knowledge about recycling and better environmental habits. With features such as multiplayer, card collecting, and using beacons, we hope to make our players more aware and conscious of their environmental decisions, while also being entertained. Our primary focus is the senior generation, for whom we plan to keep things simple, in terms of both usability and design.

We expect to raise the player's awareness of their choices and actions on a daily basis and realize their impact on the environment, by creating a better sense of responsibility and motivating more families into creating good recycling habits. The aim is to promote intergenerational care, education, and well-being, by imbuing the older player with recycling habits. So, in our game, players are challenged to virtually do the sorting exercise (separate garbage in-game), which creates a bridge between the in-game and the real-world recycling, that is achieved via geo-reference modules and beacons.

The game is also important to the development of different competencies and skills, such as decision making, memory skills, drive for results, and education on how to recycle. This acquired knowledge of the players will be evaluated by the in-game score and their position on the overall ranking. By tracking beacon usage metrics and cross-referencing with player data, the "conversion rate" can be obtained, providing insight into how many players are led to recycling more after playing the game.

The approach to this project is to launch the game on the app stores. In an initial phase, we plan to consider only a small area, where a small number of beacons can be spread in recycling points. This would serve as an initial test of our concept. Since it is meant to be tested on a local scale, it also means that it will be easier to collect additional information and feedback early on from players. The next steps would be to secure a connection with distributors or even proper institutions, to finance and distribute the beacons across recycling points. Notwithstanding, there needs to be a heavy investment in an advertisement – we would aim to target TV ads and influential people among the older generations to spread the idea and use of our game. Finally, we should secure a partnership with a company that will control, monitor, and maintain the beacons, replacing those that need to be replaced and adding more, covering wider and wider ranges of recycling points. Another option to consider is a partnership with a company that is responsible for waste collection and processing like Lipor, they could promote this game as a plan to educate people on the process of recycling.

3.2 Objectives

The Eco Tetris game aims to promote better recycling habits to reduce the climate impact, raise awareness towards good environmental decisions, and enhance sustainability and global responsibility. This project is focused on creating a digital tool and digital content to be available on different platforms and to every player. By focusing on the older generations, the game relies on its easiness, inclusiveness, and intuitiveness.

For that purpose, Eco Tetris will pursue a set of specific objectives, such as enhancing intergenerational care, education, and knowledge about ecology. Creating a better sense of global responsibility will contribute to promoting sustainability and well-being. In concrete, this game will pursue the following specific objectives:

- Increase recycling and environmental habits;

- Enhance intergenerational care, by motivating people to do recycling;
- Reduce waste disposal and limit climate change impact on the maintenance of planet Earth;
- Promote knowledge and education for older generations towards social responsibility and sustainability;
- Create a tool that allows raising awareness following the 2030 Agenda for Sustainable Development of the United Nations.

By creating and implementing Eco Tetris it is possible to develop a better sense of social and global responsibility towards sustainability among the older generations, and in a near future, we hope to do the same among younger generations, to educate them with their first recycling habits.

4. Game design and architecture

At Eco Tetris game architecture it was conceived a built-in ambiance and environment referring to a setting that was created within the game. It is how the user experiences the recycling habits with a realistic virtual background making the interaction for the player more realistic.

4.1 Software architecture

There is a representation of four different layers and each of their components Figure 1.

The Presentation Layer is responsible for handling all the user interface logic, allowing the user to effectively interact with the system. The UI_Controllers component acts as a bridge between the first and the second layer, allowing the data communication between them.

The Business Application Layer represents the core of the application. Each component in this layer provides an interface so that other components can make use of it, such as the UI_Controllers mentioned before.

The Persistence Layer provides simplified access to the database's records, such as performing CRUD operations. This way, we can summarize these database calls from the Business Application Layer, making the system more compact and modular.

Finally, we have the Database Layer that contains a database server that is responsible for all the application's data storage and persistence, which the previous layer communicates with, to fetch data for instance.

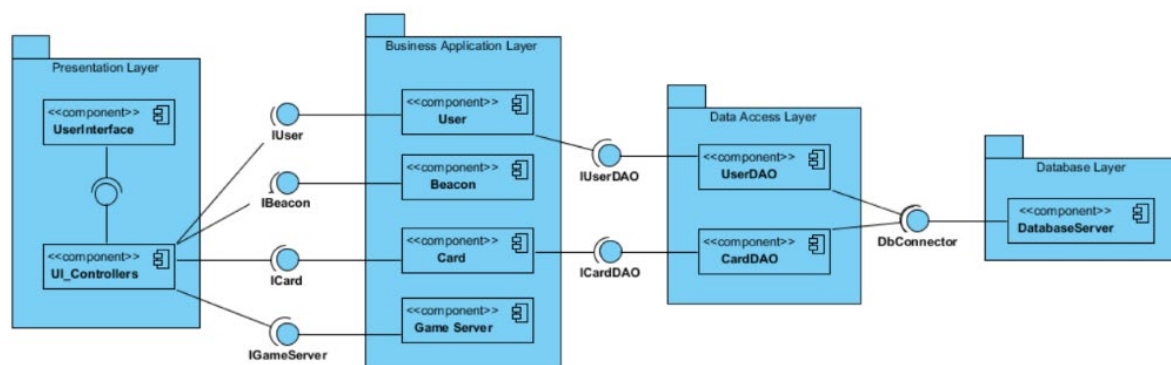


Figure 1: Software Architecture Diagram

It is also important to mention the hardware systems involved in the application Figure 2. This way, the main intersections of the application are the end user's device which is running the mobile application, the server that contains the application logistics and communicates with the app via HTTPS, and the server storage. The following image represents a Deployment diagram, modeling the physical aspects of the proposed system.

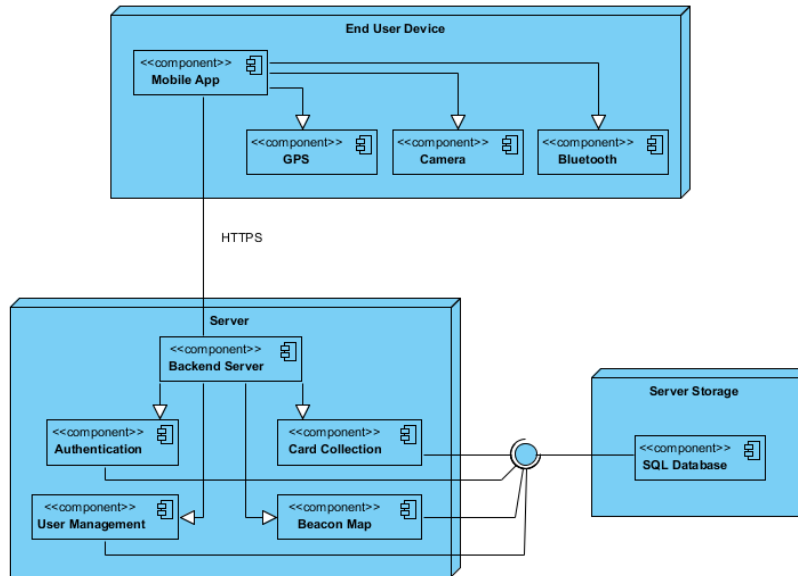


Figure 2: Software Deployment Diagram

4.2 Gameplay

The Eco Tetris game was designed and developed to be intuitive and educational. The following images intend to demonstrate and describe the gameplay and the features of this application.

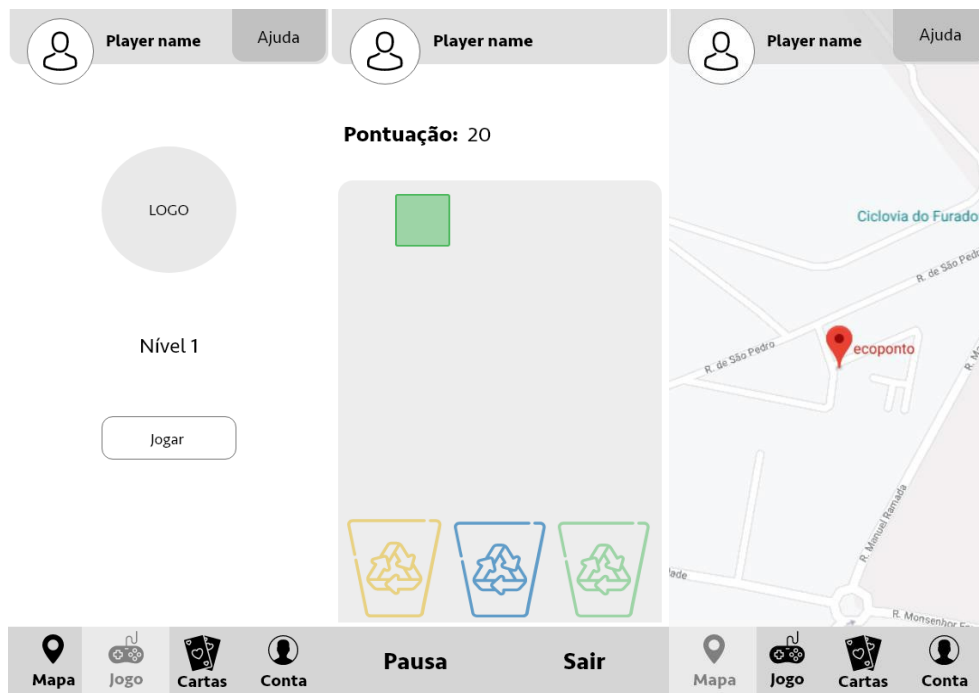


Figure 3: Gameplay

The first screen refers to the application's main menu, where it is possible to access the settings, access explanations of how the application works, start a game, view the card collection and access the map. The second screen refers to the game itself that is meant to teach how to recycle. The upper left corner will contain the user point information. The bar at the bottom of the screen allows exiting the game or pause it. Finally, the last screen is where the user can check where the nearest ecopoints are and actually contribute towards a more sustainable environment.

4.3 Game flow adjustment

Eco Tetris is designed in a way that difficulty can be scalable, to always keep the player within the “flow zone”, and not too challenged or bored. The game uses DDA (Dynamic Difficulty Adjustment) in order to regulate this. The DDA allows for the game to automatically adjust its difficulty to the player’s performance throughout the gameplay (Oostendorp, et al., 2014).

Thus, the game controls the number of “hits” (correctly placed pieces) and “misses” (incorrectly places pieces). If the player is getting a considerable successful number of correctly placed pieces, it is safe to assume the game is not being challenging enough, and there is a need to scale the difficulty – this will be done by increasing the sleep of falling blocks (gradually, so that it can be nearly imperceptible), and by spawning randomly blocking pieces that will force the player to skillfully navigate around them. The reverse is also true; should the player begin to place many incorrect pieces, these elements that increase difficulty disappear, and the falling speed is reduced.

5. Evaluation and Quality Scenario Control

To assess the Eco Tetris game development and its quality control, we chose to use the Quantitative Evaluation Framework (QEF), which aggregates a set of dimensions, factors, and requirements. We’ve determined that the focus of this methodology would be functionality, adaptability, and usability (Table 1). To better assure that the game meets its evaluation criteria, the product was assessed during its development using the QEF framework, to have a clear view of its quality. The quality of the game, assessed by this framework, legitimates the system’s performance.

Table I: Quantitative Evaluation Framework (QEF)

Dimension	Factor	Requirement
Functionality	Player Interaction	Control falling piece
		The clear line of pieces if in the correct order
		Player gains score points each time a piece is placed on the map
		Columns are associated with a type of recycling bin (green, yellow, blue)
		Pieces have a different color depending on trash type (green, yellow, blue)
		The player passes level if he reaches a certain score
		The player loses 3 times in a row, the level is decreased, power-up awarded
		Get power-ups
		Show player scoreboard
		Higher difficulty means increasing the block's falling speed or more columns
		Background can have different appearances
		Some levels have obstacles on the map
	Multiplayer	Play local multiplayer in turns
		See the score and who won
		Previous multiplayer scores are stored
Collection	See card collection and information	
	Get a card from beacon	
	See the map with the location of the beacons	
	Create a player's card	
Profile	Create profile	
	Account login	
	Country flag depending on user location	
	The player can customize his avatar	
Adaptability	Versatility	Applications are shown in their environments in a native way
		The application adjusts to screen resolution
	Gameplay	Game difficulty is adequate and adjusted
	Maintenance	The application's sensitive data is encrypted
		The server must be scalable
		Players can download DLCs with more avatars
	The game is appropriate for older people	
Usability	Menu Navigation	The product has a good structure and allows users to access content in an intuitive way to the main functions
		Unallowed user actions must present a clear warning/error message
	Learning	The player learns which type of trash should be placed in each type of recycling bin
		The player learns about the location of recycling bins

Dimension	Factor	Requirement
	Game	Important player actions have feedback to inform the player
		Augmented reality
	Support	Player data is protected from unauthorized access
		The game is stable and executes systematically without failures
		The game is multiplatform
		The game has multiplayer
		The game is closed source
	Content Quality	The texts are well written, and all the sentences make perfect sense
		All the messages are easy to understand
		All messages should not contain racist, xenophobic, or antisemitic content
		All content is related to the game
		All the text has the appropriate font size for older people

The team used QEF framework to evaluate the educational software quality based on the standard of reference ISO 9126 and SCORM. The system quality is in the inverse proportion of the distance between the Ideal System and the Real System. The closer the Real System is to the Ideal, the higher the quality percentage will be attributed to the real one.

For this, all the requirements were listed, metrics for their measurement defined, and weights for the final grading were attributed to them. Some of the requirements' fulfillment is measured through quality assurance tests, and for the requirements related to the user experience and interaction, surveys are performed.

5.1 Eco Tetris: functionality, adaptability, and usability

The functionality of the game consists of different evaluation criteria that are the core of the product's function. This dimension was divided into four factors such as player interaction, multiplayer, collection, and profile, and each one of them is composed of several requirements.

The adaptability of the game consists of its capacity to adapt to new conditions and features, all players, and all platforms, by making the game more inclusive and scalable. This dimension was divided into three factors such as versatility, gameplay, and maintenance, and each one of them aggregates different requirements to ensure the good performance of the game.

The usability of the game consists of its effectiveness, which relies on the conveying of the correct information and the fulfillment of its purpose- teaching about recycling. This dimension was divided into five factors such as menu navigation, learning, game, support, and content quality.

6. Conclusions

Raising awareness towards recycling and good environmental habits can be of extreme importance to the maintenance of our planet, our well-being, and the sustainability of the environment. Motivating people to become more conscious and proactive can be achieved by different approaches, namely through a serious game. Games can be a great tool for education and enhance the learning process. In the case of Eco Tetris, useful for every age, it is possible to watch the increase of knowledge of the older generation through regular contact with technology.

But not only the older generation can benefit from this tool. Should the development of this project continue, it would be important to further test the existing features and maybe even add new ones. It would be interesting to deploy and publish the software to a wider audience and establish a partnership with companies in order to deploy beacons in all the recycling stations and eco points, allowing for an extended user test and greater feedback to add new features and improve existing ones. Furthermore, the target audience can also be expanded, and the game could turn out to be of greater use in the classroom, to teach younger generations their first recycling habits.

In the end, the Eco Tetris serious game aims to enhance intergenerational care, social responsibility, sustainability, and better planet development. With that in mind, we can expect that the Eco Tetris serious game generates an innovative approach towards sustainability, within the features of education and learning through technological tools.

Acknowledgments

This work is being developed at the research group GILT – Games, Interaction and Learning Technologies from the Polytechnic Institute of Porto, with the support of FCT/MCTES Financiamento Plurianual Base da Unidade (UIDB/05627/2020).

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