Learning how to recycle waste using a game

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ABSTRACT

Proper waste sorting is crucial for both economic and environmental reasons. Yet, its effectiveness can be strongly limited when citizens do not know how to correctly separate waste, sometimes even due to different regulations depending on their municipality. We have hence devoted our efforts to the creation of a serious game able to teach people of all ages how to match the various trash cans with the corresponding type of waste. Although we have considered the city of Padua, Italy, as a case study, our application can be easily adapted to different waste sorting regulations.

CCS CONCEPTS

• **Applied computing** → **Computer-assisted instruction**; • **Human-centered computing** → **Collaborative and social computing systems and tools**.

KEYWORDS

Recycling waste, Serious games, Mobile applications

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1 INTRODUCTION

The problem of waste management is one of the key concepts at the core of sustainable development and has been recognised even by world leaders [18]. Sustainable development means a more beneficial interaction between humans and environment, as well as more attention to preserve the ecosystem and the natural resources upon which the economy and our society depend [22]. A key to promote environmental efficiency is the adoption of effective waste collection and management and, in this context, waste sorting is well known as an essential requirement [3, 4].

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The European Union has promoted the development of an integrated network of waste collection systems that manages recycling from the production phase to the recovery or final disposal. The European Waste Directive 2008/98/EC imposes to the EU members different mandatory recycling levels depending on the waste fraction. Citizens and companies are required to separate the Municipal Solid Waste (MSW) by type, e.g., food waste, green waste and recyclable materials (paper, glass, plastics, metals, etc.). Public authorities are strongly invited to comply with the collection requirements for different waste streams set in the waste legislation [35]. The 2019 Italian report on recycling and waste management reveals that the cost of waste collection and transport accounts for the 13.2% of the total cost of unsorted MSW management and the 23.4% of the cost of sorted MSW management [16].

Sorting garbage is a relevant topic in many countries both for economic and ethical reasons, since it contributes to environmental protection. Empirical evidence suggests that not all people separate waste in the proper way, potentially because they do not know how to do it correctly or simply because they are not motivated enough.

In this paper we present *PadovaGoGreen*, a serious game to teach people how to match the various trash cans with the corresponding type of waste. Incorrect waste sorting prevents efficient recycling. One of the main problems that lead to this drawback is the users' lack of knowledge also fostered by the fact that regulations can change depending on their municipality[1].

The use of *serious games*, i.e., games with a serious intent, to promote behaviour change and to motivate users is widespread [9, 11, 13, 18, 23, 28, 30] in many fields including urban/society-related ones [19, 21, 24, 25, 29]. Many studies have demonstrated their effectiveness in lowering the drop-out-from-therapy phenomenon [6, 14] and in improving rehabilitation therapies [7, 8, 12]. Serious games are also used in formal education environments: "Coding Pirates" [32] is a serious game for primary and secondary school that aims at introducing basic concepts of programming through a treasure quest. Mayo [20] demonstrated that using serious games at school increased pupils' achievements up to 40%. Moreover, Young et al. [38] found evidence of positive effects of the use of serious games on language learning, history and physical education. A collaborative serious game approach has also been successfully tested for the generation of lecture transcripts that can then be used by all students [10].

[1] *PadovaGoGreen*, *Padova* is the Italian name of the city of Padua in Italy, is intended for the municipality of Padua, in Italy, but it can be easily configured to be adapted to other different regulations.

Serious games are not only for students: employees of two hospitals in Denmark learn best practices using IT systems with a quiz game [34]; similarly, Velux company uses a serious game [33] to teach core values and management principles to new employees.

The *serious* intent of our game is to improve knowledge about waste separation according to the regulation of the municipality of Padua. The citizens of Padua can already use another mobile app to find out the correct can for the various types of waste, the nearest waste management facility and the schedule of the residential recycling pickup. The app is named *Il Rifiutologo* [15] and has been developed by Hera Group. It consists in some information and a simple form for inquiries. Obviously, this approach fails in engaging the user to learn regulations; still, it is useful to quickly find the answer to a set of possible questions. *PadovaGoGreen* has a completely different intent. Our goal is to involve people in learning Padua's regulation about waste sorting, while having fun.

The paper is organized as follows. Section 2 describes the related work present in the literature. Section 3 describes the game, its levels and tutorials and its implementation details. Discussion on a user study is presented in Section 4. Finally, we draw our conclusions in Section 5.

2 RELATED WORK

Other works in literature address the problem of improving knowledge and behaviour of citizens in waste recycling to contribute to environmental protection. Lessel et al. [19] investigated people's capabilities to sort waste and how they improved their skills over time. The study confirms that the *wisdom of crowds* is applicable in this context as the crowd produces only half as many errors as the individual; thereby, feedback from the crowd can help participants to become better recycling citizens. For this reason, they created a mobile game app which proposes various objects to the users asking to sort them and *The Trash Game*, a public trash can that is able to take a picture of the discarded object and give feedback based on answers collected by the mobile app. The system is intended to educate playfully both the crowd running the game and people using the trash can.

Fox the Recycler [31] is a game intended for student age group to boost recycling activities. It was tested in fall 2018, in student apartments in Kuopio (Finland). After the pilot, the recycling rate of biowaste increased from 76% to 97% and the recycled plastic from 25% to 84%. The study showed that gamification is an efficient solution to support a change in consumers' behavior, thus demonstrating that gamification and serious games can be used also with young adults and not only with children.

Wang and Ibánez [36] evaluate a Kinect educational game where students learn to recycle using body gestures. The focus of the evaluation is the investigation of potential advantages using gesture interfaces in educational games, as well as how the game affected the students' engagement, motivation and learning. The results show that primary school students get highly motivated and engaged playing a Kinect recycling game. Moreover, the study highlights that students preferred such game-based learning to traditional lectures and playing this game as a multi-player game, where the boys preferred to play competitively while the girls preferred playing collaboratively.

ARGreenet [18] is an Augmented Reality mobile phone game that raises the awareness about recycling and its rules. The game was tested with 38 children aged from 8 to 13 that also answered to questionnaires before and after using the game. The authors reported a positive change in recycling and that the mobile phone is potentially a good platform learning recycling rules and influencing people to change their behaviour.

Another serious game to teach recycling rules is *Recycling Monster* by Jacob et al. [17]. It is a mobile app which teaches to correctly separate the falling trash before it is eaten by the hungry recycling monster that craves for that trash. Players have to drag the trash items to their respective containers. This game is similar to the one we developed, but there is an important difference: the graphic interface and the use of a monster limit its use to children and not to adults. Our goal is to reach a wider audience.

Centiero et al. [21] exploited the use of games as entertainment mechanisms to promote education, social relationships and behaviour changes. They developed *Gaea*, a persuasive location-based multiplayer mobile game, which prompts people to recycle virtual objects within a geographical area. The goals of this prototype are to instruct, inform and persuade users to recycle their waste. The authors wanted to reach a large number of people using natural environment and foster social engagement. Players use a smartphone to locate and collect the virtual litter in their surroundings, which should then be dropped into the correct virtual recycle bin, available for selection when approaching the public display. *Gaea* raises users' awareness to the impact of their actions on our planet's natural resources and promotes users' physical activity.

Similarly, Prandi et al. [27] developed a mobile serious game, which aims at supporting preschool and primary school children in understanding two important concepts: topographical orientation and recycling. In this case, children have to move a humanoid robot in a grid, named MecWilly, to help it to throw specific garbage in the right recycling container. The outcome shows that kids were very interested in playing such a game and in experiencing more game levels.

Aguiar-Castillo et al. [1] define as *gamipulation* the use of game-design elements that impel the user towards undesired behaviors. They designed a theoretical model that has been validated through a survey of 79 experts in a set of pilot cities. The results showed that only the expected social benefits and the perceived risks (e.g., security) have a direct and significant influence on the intention to adopt the sustainability application based on gamification. They developed *WasteApp*, an application to help to recycle waste, adopting this theoretical model.

These studies show that serious games and gamification techniques can be used to involve users of all ages, improving their consciousness on the problem of waste recycling and teaching them how to do it.

Yet, they also show another problem: games and applications for waste sorting are ironically not recyclable because laws and regulations change according to the country and the specific geographic area. For instance, *Wise up to waste* [37] is a mobile game to learn about recycling in London and cannot be used in other countries, both for the use of different languages, but also for different regulations. In Italy, *il Rifiutologo* [15], can be used in Padua, but not in Venice, even if both the cities belong to the same region.

(a) (b)

Figure 1: (a) *Sansone, the trash can* that introduces the game to the user; Sansone says: "Hello! I'm Sansone, the trash can and this is the game to learn sorting waste in the municipality of Padua"; (b) screenshot with the levels of the game.

(a) (b)

Figure 2: Two screenshots of *PadovaGoGreen game*: (a) the quiz; (b) gameplay during a level.

In this paper, we discuss our (serious game) application that shares similar goals with the app *il Rifiutologo*; yet, while the latter is just an information provider, our app applies gamification techniques, demonstrated to be efficient in changing social behaviours. Also, our app has been designed to allow an easy configuration of the game in such a way that can be used even in different cities.

3 DESCRIPTION OF THE GAME

PadovaGoGreen is an educational game for mobile devices. It aims at teaching people, in a funny way, the regulation about how to sort waste to allow recycling. A funny mascot, *Sansone, the trash can*[2] guides the user for the entire game[3].

At the begining, it introduces itself and asks for help to keep clean the city of Padua, as shown in 1(a). It guides the user providing advice every time he/she finds him/herself in a new situation, i.e., the first match, a new level, etc.

Since it is intended for the city of Padua, the game has been implemented in Italian. For this reason, the background of the game is a picture of *Piazza dei Signori*, one of the main squares in Padua. The underlining idea is that if the user learns how to correctly sort waste, the city will be cleaner for everyone; conversely, if the player fails in sorting waste, a mountain of garbage is depicted over the square, as depicted in Figure 2(b).

The game asks the user to register/login to record his/her performance and improvements. Information saved includes the name chosen by the user, his/her genre and range of age, his/her city district and performance in the game. Moreover, the game also provides a manual: different types of waste are listed in alphabetical order along with the correct trash can or trash management policy. The manual was implemented to completely replace the app *Il Rifiutologo*, which only serves as information provider as already discussed at the end of Section 2.

The game has six levels (see Figure 1(b)), in which the player has to guess the highest number of correct trash cans. Each level begins with a quiz with three questions. In Figure 2(a) the question is: "Which is the correct trash can for a mirrow?". The player must answer correctly to at least two questions out of three to access the level. During the gameplay, different kinds of waste fall from the ceiling and the player has to move each object into the correct can, choosing between three options, before it falls on the basement. If the player chooses a wrong answer, a mountain of waste grows up in the background as depicted in Figure 2(b).

Obviously, the game can be paused and help is provided if needed to remember the type of each different can (see Figure 3). Moreover, before getting access to the first game level, the user has to play with a tutorial which teaches how to move the objects.

As the level increases, so does the difficulty of the game: for instance, during the first level, presented objects are easy to sort (e.g., fruits and some commonly used objects made of glass and plastic such as bottles and jars). Further on, the game shows less trivial objects, including smartphones and televisions. Moreover, the falling speed of the objects increases during higher levels.

At the end of each level, Sansone explains the errors to the player to improve his/her knowledge about waste sorting: in Figure 4(a) the player has correctly thrown a hair brush in the trash for non-recyclable waste; in Figure 4(b) the player has made an error since plastic dishes can be recycled using the plastic trash can.

[2] In Italian, *Sansone, il bidone.*
[3] A video showing the game can be seen at https://mega.nz/file/sZpnjZ4B#DfAfI0cOlnlOaQepxutsQbO7eN_jxle85ewzaY_3oU

Figure 3: Help provided during a level; the name of different waste is shown, i.e., "umido" is the food waste (wet waste), "vetro" is glass and "plastic" stands for plastic.

(a) (b)

Figure 4: Feedback at the end of a level: (a) for a correct answer; (b) for a wrong answer.

3.1 User interactions

Since the target users of the app is very general, i.e., children, young adults and adults, the interface has been designed to be very simple and intuitive. This should foster the involvement of users through fun, but without too many game elements. The app's background portrays the city of Padua and the main color is green which represents the separate collection of waste and, in general, recycling.

The results of quizzes and the game's levels are displayed with three different colors, i.e., green, yellow and red, to provide the user with a positive or negative feeling based on his/her performance, e.g., in Figure 4 the right answers have a green font (a), whereas the wrong ones are coloured in red (b). The application uses also music and sounds to make the game more interactive and engaging and to provide feedback: the app uses different sounds whenever there is a wrong or a right answer to correct or reward the player.

3.2 Tecnical implementation

We have developed *PadovaGoGreen* using a cross-platform development framework, called *Corona*[4], which allows to develop games once and then distribute the app both on Android and Apple platforms. Corona requires the use of the *Lua* scripting language[5], an intuitive language both for advanced developers and beginners. Moreover, the framework offers a complete documentation with many tutorials to quickly grasp how to use APIs and plugins.

We used this framework because it contains several libraries specifically designed to create games and to manage the physics of objects. The library named *Physics*[6] is used for apps that involve a simulation of objects that move, collide and interact under various physical forces like gravity. Through this library, it is very easy to add laws of physics to moving game objects, even for developers that never worked with a physics engine before. In our application, physics' library is mainly used to manage the waste falling down while the player tries to drag it into the correct trash can.

Furthermore, we have used the *Composer* library[7] to structure the game; in particular, each level and quiz of the game is represented by a scene which is managed with this library. The library allows to develop the switch between scenes, i.e., quizzes, levels, menus and score visualization.

In order to collect the data, the application is connected to Atlas MongoDB[8], a well known cloud database service. MongoDB is a document-oriented database characterized by high scalability and flexibility. This database allows us to easily manage and send JSON files used in our app to store data about users' profiles and scores.

When the mobile device is connected to the network, the application sends data to the online database using asynchronous HTTP requests to the online database identified by an URL. The data are sent at different times during the game; in absence of an Internet connection, the application does not block the game and does not loose data but it simply saves data and sends them as soon as possible.

The database stores the following data for each user:

- username, gender and age
- neighborhood
- passed levels
- the quiz's score and the percentage of accuracy in the game for each passed level

[4]https://coronalabs.com
[5]https://www.lua.org/
[6]https://docs.coronalabs.com/api/library/physics/index.html
[7]https://docs.coronalabs.com/api/library/composer/index.htm
[8]https://www.mongodb.com/cloud/atlas

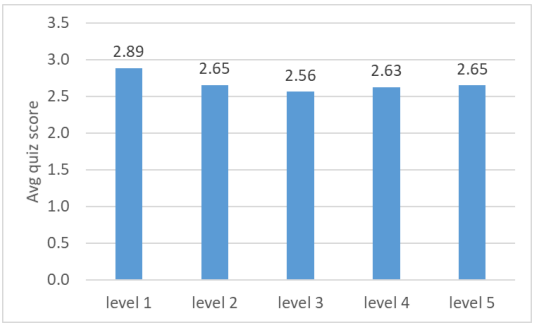

Figure 5: Avg quiz scores on each level considering all users.

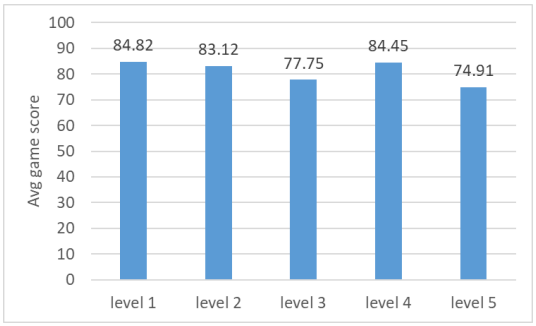

Figure 6: Avg game scores on each level considering all users.

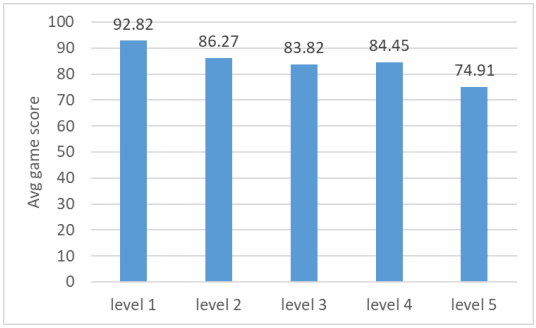

Figure 7: Avg game scores on each level considering only users that completed all the levels.

3.3 Game vs reality

Since the goal is to improve the players' knowledge in terms of waste sorting, we have developed our game binding it with images of real life objects like a fork, a hat, a dish, etc. Every level has different types of waste to progressively increase both the game difficulty and the set of waste the user learns to correctly recycle. As an example, it is easy to sort food waste, but not everyone knows that broken smart phones must be brought to the nearest waste management facility.

Colors, sizes and shapes of the trash cans deeply vary according to the considered municipality and type of house in which people live. In *PadovaGoGreen* we have used colors and shapes as imposed by Padua municipality's regulation. Furthermore, the colors employed for the quiz answers match those of the corresponding real trash cans, as shown in Figure 2. This let players memorize the different colors of trash cans through the fun of a game.

4 TESTING THE GAME

We have shared the game with 20 potential users, in a 20 to 45 years old's range, to collect their feedback and scores. The collected data show that all the involved users had at least some knowledge about waste sorting. This is demonstrated by the results achieved in the quiz part of the game (see Figure 5) where, in most cases, either 2 or 3 correct answers (out of 3) were chosen correctly.

Even Figure 6 presents a positive outcome; the chart shows the average game score for each level, considering all matches played by any player. However, both in Figure 5 and in Figure 6, we can notice lower scores for level 3 than for level 4. This unexpected result is not due to an improper configuration of the difficulty of the two levels. Simply, level 3 resulted to be the first level significantly challenging for the users both in terms of speed and correct separation of waste. For this reason, it represents the level that has been repeated more times by the users before being able to proceed to a new one, i.e., 1.71 times in average, against values between 1 and 1.3 for the other levels. Furthermore, about 30% of users did not proceed to upper (and tougher) levels of the game. These users basically gave up at a certain point during level 3, thus achieving quite low scores during that level and affecting the final average.

Indeed, if we report the same metrics in Figure 7, but this time considering only users that went through the whole game, till the end of all five levels, we get a smoother decrease of the reported values from level 1 to level 5, without the pit in level 3 present in the previous charts. In any case, letting the users struggle a little with level 3 was not in vain. If we consider only users that repeated level 3 more than once and we compare the minimum and the maximum values achieved by each of them in their repeated attempts, we end up noticing a significant improvement of these users' skills; in fact, the average minimum is 49.3, whereas the maximum reaches 78 in average.

To get feedback from the users, we administered a brief questionnaire. First, we asked them to rate our application on a scale from 1 to 5, with 5 being the top value: 9 users rated it 4 and the rest of them (11) chose the highest rate. Even more interesting, we asked the users to reveal whether the game made them realize they were wrongly sorting some type of waste and the majority (12 out of 20) confirmed it. This proves the efficacy of our serious game in reaching its educational goal, allowing users to improve their waste sorting skills.

Unfortunately, the limited amount of data collected so far prevents us from performing a thorough data analysis with respect to the age and the neighborhood of users. The municipality administration of Padua could use our application for its awareness campaign about waste sorting. In this way, it could be possible to collect more data about the population's participation and to understand where efforts should be focused using, for instance, the age or the neighborhood as parameters. In addition to this, the awareness campaign could be more effective by involving children who certainly enjoy learning while having fun at the same time.

5 CONCLUSIONS

In this paper we have presented and discussed *PadovaGoGreen*, a serious game developed to let people learn how to match the various types of waste with the corresponding trash can to increase waste recycling effectiveness. Through our app, users can have fun while learning correct waste sorting practices and regulations related to their specific municipality. As a result, we can expect to increase the citizens' participation in recycling.

This work has generated encouraging preliminary results; we plan now to extend it in several directions. First of all, we would like to perform a more thorough set of tests involving a wider audience of users. Furthermore, it would be interesting to endow our application with the possibility to interact with the real environment (e.g., objects, trash cans, locations) in order to integrate the game into a crowdsensing system [2, 5, 26].

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