VALUE OF A MOBILE GAME-BASED APP TOWARDS EDUCATION FOR SUSTAINABILITY

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ABSTRACT

The local environment can be explored to sustain effective sustainability learning. With this aim, new learning methodologies can be fostered, namely mobile and game-based learning, as is the case of the EduPARK app. This app supports innovative learning strategies through treasure hunt games, integrating multimedia and augmented reality resources, in natural spaces. This paper presents a pilot case study of a pedagogical approach based on the exploration of a game in the EduPARK app, in the outdoors. The game was developed to be explored in the largest annual event of the University of Aveiro (UA) – XPERiMENTA 2022 – where students of several ages and the wider community are invited to participate in diverse activities on the campuses. The main goal of the activity "XPERiMENTA with EduPARK in the UA Campus" was to raise basic education students' awareness towards nature conservation. Eighteen students (14 and 15 years-old) explored an interdisciplinary educational game that encouraged them to follow a path through the UA Campuses to promote learning related to recycling, renewable energies, food waste, and ocean plastic pollution. Simultaneously, curricular contents of Science, Mathematics, Education for Citizenship, and cultural aspects of the city of Aveiro were articulated. At the end of the activity, an individual and anonymous questionnaire to evaluate the activity was applied. Students revealed a positive attitude towards the EduPARK app, as their answers revealed they felt motivated to learn during the game. Additionally, students reached a good performance in the game, although difficulties in one specific question were identified. This paper presents preliminary results that will inform the development of a new related project, the EduCITY, that aims to promote education for sustainability through a smart learning city environment.

KEYWORDS

Mobile Learning, Outdoor Learning, Game-based Learning, Augmented Reality, Education for Sustainability, EduPARK App

1. INTRODUCTION

We are witnessing a vast set of global challenges, which demonstrate the fragility of the planet and the effective need for human development to be sustainable. To mitigate the decades of exhaustive use of natural resources and the consequences of climate change, the adoption of a set of global, and integrative actions needs to be reinforced, to reduce the effects of human development on the natural and social environments. Actions to address this problem must involve the community and need to be structured and developed both at global and local levels (United Nations, 2015). They should also take place in outdoor environments, in direct contact with the local reality, anticipating benefits in terms of learning and well-being (UNESCO, 2020).

From the above, sustainable development must become an integral part of our daily lives. Education for Sustainable Development is a lifelong learning process and a fundamental part of quality education. It improves the cognitive, social, emotional, and behavioral dimensions of learning, as predicted by the United Nations (UNESCO, 2020). Moreover, the 2030 Agenda for Sustainable Development is a plan of action for people, the planet, and prosperity, so Education for Sustainable Development should consider and contribute to these goals.

Mobile Augmented Reality (AR) technologies can be suitable and engaging pedagogical tools for Education for Sustainable Development, as they enable students to learn and reflect on their behaviors. Altinpulluk (2019) mentions that tablets and smartphones are the most used devices that support AR in

Education, and that its most positive effect is on academic success and learning motivation. In the last decade, the evolution of mobile technology provided the emergence of mobile learning as a natural consequence of the development of new ways of digital communication in society.

Mobile learning is the use of mobile technology to facilitate learning anytime and anywhere. According to Su and Cheng (2015) "mobile devices can create more active learning experiences, which improve student engagement, learning and course retention, and the use of new technologies can amplify motivation, which is a vital aspect of learning, deliver information when needed, and encourage students to solve problems and satisfy their curiosity" (p. 269).

Thus, it is imperative to use mobile technology in order to provide better access to the learning process (Almaiah, Al-Khasawneh & Althunibat, 2020). The proliferation of mobile technology offers possibilities to revolutionize education, combining mobile learning and game-based learning approaches (Li & Tsai, 2013). Game-based learning provides an environment where students can learn using gaming through mobile devices. Students are engaged in it, not only for leisure pursuits but also for educational purposes, consequently, their motivation is improved when they play games while learning (Prensky, 2001). Also, mobile devices can support game-based learning approaches in the outdoors (Özdener & Demirci, 2019). With these devices, the learning environment accompanies the student everywhere.

An example of the promotion of such innovative approaches is the EduPARK project (Pombo, Marques, & Oliveira, 2019). The EduPARK is a research and development project, funded from 2016 to 2019, that developed innovative, attractive, and interdisciplinary teaching strategies. The project created an interactive app for authentic interdisciplinary learning, supported by mobile and AR technologies, in a game-based learning approach, to be explored by educational stakeholders from all school levels and the wider community. One of its innovative aspects is the displacement of the learning experience from the classroom to the outdoors, moving learning to the green park Infante D. Pedro, in Aveiro (Portugal) (Pombo & Marques, 2019). The app was developed to be explored specifically in this park in order to support authentic and contextualized learning, as it prompts users to observe this outdoor environment and to access AR content through image-based markers. This option allows students to physically explore natural spaces, while making connections with curricular content (Paixão, Jorge & Martins, 2013).

The EduPARK project developed a set of interdisciplinary educational games aimed at different publics; however, only one educational game was focused on sustainability topics (Rodrigues, 2021). In order to identify the potential of the EduPARK app to promote Education for Sustainable Development in basic education students, through mobile and game-based learning strategies in the outdoors, a pilot study was conducted. Its preliminary results are presented in this paper and support a set of lessons learned that contributes to the area of mobile AR games for learning. These will also inform the development of a new related funded project, the EduCITY, which aims to promote quality education for sustainability through a smart learning city environment.

The next topic in this work describes the study's methodological options, which include the description of the pedagogical approach, materialized through the "XPERiMENTA with EduPARK in the UA Campus" activity. Data collection and analysis procedures and tools are also presented in this section. Follows the results presentation and discussion section, based on the results obtained through a student questionnaire. Finally, some conclusions are put forward.

2. MATERIALS AND METHODS

This paper reports a pilot study that fits a case study research approach (Amado & Freire, 2017). It aims to answer the research question "What is the potential of a mobile game-based learning strategy, based on the EduPARK game explored in the «XPERiMENTA with EduPARK in the UA Campus» activity, to promote Education for Sustainable Development in basic education students?". The game was designed in alignment with a previous game developed under the Ph.D. work of this paper's first author (Rodrigues, Pombo & Neto, 2020).

This section comprises two subsections: i) a description of the "XPERiMENTA with EduPARK in the UA Campus" activity for context; and ii) data collection and analysis approaches and tools.

2.1 The "XPERiMENTA with EduPARK in the UA Campus" Activity

The developed pedagogical approach comprises an activity framed in the **XPERiMENTA** 2022 event. This is one of the biggest events of the University of Aveiro (UA), directed at basic and secondary school students, as well as at the wider community. This event invites participants to explore hands-on activities, interactive projects, scientific experiments, and guided tours through the UA Campuses. The context of this big annual university event facilitated the recruitment of volunteers to participate in this study.

The main goal of the activity "XPERiMENTA with EduPARK in the UA Campus" was to raise awareness towards nature conservation in basic education students and to promote their learning related to the topics: recycling, renewable energies, food waste, and ocean plastic pollution, articulating curricular contents of Science, Mathematics, Education for Citizenship, and cultural aspects of Aveiro city.

The activity required playing a specific game with the EduPARK app. It was an interdisciplinary educational outdoor quiz, in a treasure hunt approach, that challenges users to find specific locations with AR markers in the UA Santiago Campus and to observe their surroundings to answer the questions.

The game integrates ten multiple-choice questions with images, audios, videos and AR contents. These are virtual information that complements the observable reality in each location. In this game, AR was integrated into the questions with two main aims: i) to promote historic patrimony preservation, which is the case of AR markers that are art tiles of the city (questions 1, 2, 4, and 6); and ii) to promote natural patrimony preservation, where AR markers are identification plaques of trees in the Campus, in this case, the Canary Island palm plaque.

Additionally, multimedia resources, such as animations and images about sustainability issues, help to correctly answer some questions and make the game more appealing (Pombo & Marques, 2019). The players always get feedback to the selected answers, whether right or wrong, explaining the right answer or giving further information on the topic associated to each question, there were AR and multimedia resources. According to Chen (2020) immediate feedback, design principles, student involvement and motivation to learn are considered the greatest advantages of using these resources in learning.

After answering all the questions, the users are challenged to find a virtual treasure on the UA Campuses. Hence, geocaching principles are explored to enhance the gameplay experience for the app EduPARK users, by finding hidden virtual treasures to promote curiosity, a powerful intrinsic motivator (Pombo & Marques, 2019).

Eighteen students of the 9th school year (14/15 years-old, both female and male) participated in this activity, which occurred in the Santiago university campus, on the 29th of April of 2022. Students were organized in seven groups of three elements. Each group played the game for an average of one hour (Figure 1), using a smartphone of the project, to reduce technological issues and concerns. The quiz game was previously downloaded to the mobile devices and no internet connection was required to play.

At the end, symbolic EduPARK prizes were given to teams with the best performance.

Figure 1. Students at the University of Aveiro during the "XPERiMENTA with EduPARK in the UA Campus" activity

2.2 Data Collection and Analysis

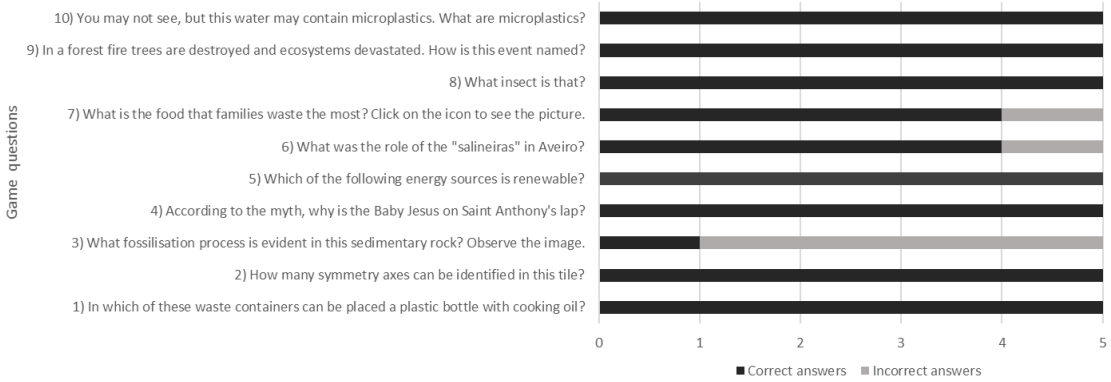
Data collection included anonymous and automatic logs of game performance, and a questionnaire applied right after the game activity. The logs of game performance included scores, the number of correct and incorrect answers, and the time of gameplay. This data was collected directly by the app in an anonymous way and allows to analyze the game's ability to support learning.

After the game, students were asked to fill in an individual and anonymous questionnaire. It comprised three questions with different objectives: i) understanding what students liked the most about the EduPARK app; ii) identifying students' opinions on the value of the game to learn about nature conservation; and iii) knowing which environmental issue from the game most concerned them. This tool included two multiple-choice closed questions (first and second questions) and a challenge with one open-ended question (third question). In this challenge, qualitative data analysis was completed, in the logic of content analysis and resorted to the categorization of responses based on the environmental issue that they choose (Amado & Vieira, 2017). The quantitative data were analyzed through descriptive statistics and the results were triangulated to analyze the value of this game for the promotion of nature conservation attitudes (Coutinho, 2019).

3. RESULTS AND DISCUSSION

Through the analysis of game logs, it is found that out of the ten questions of the game, seven questions were correctly answered by all groups (Graph 1). These questions explored curricular content or cultural aspects of Aveiro city, including the topics: recycling, renewable energy, and plastic pollution.

Regarding the remaining questions, one related to fossilization processes stands out, because only one team selected the correct option. The questions six and seven, about "salineiras" (women who work in salt pans) and food waste, only one team selected an incorrect option in each one. These three questions included image resources that could be analyzed by the students to support the answer. The results suggest that most groups of students achieved a good game performance although the question about fossilization may need improvement.



Graph 1. Number of correct and incorrect answers in the game

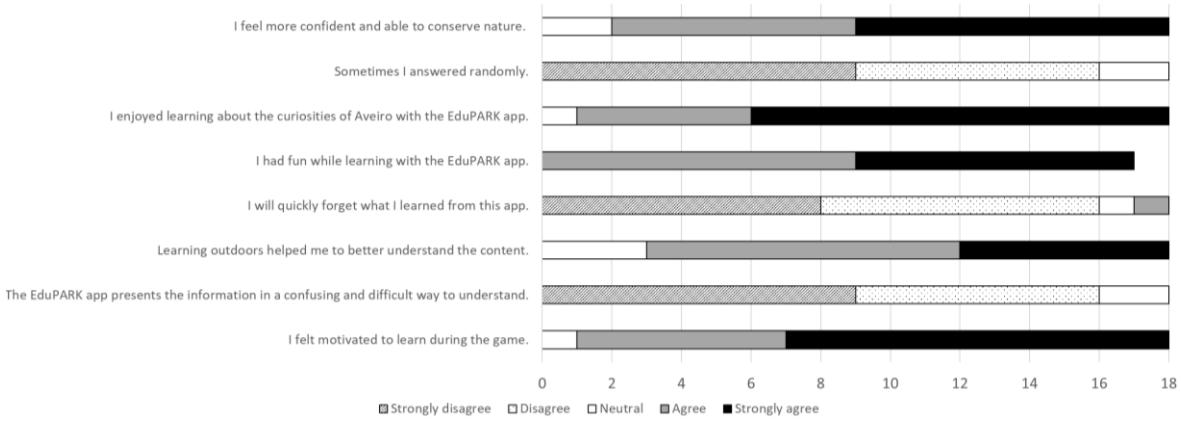
As referred, after the quiz game, students filled in a questionnaire. Students revealed that the three features they liked the most about the app were being at the UA (16 students), playing an educational game (12), and exploring AR (11). Graph 2 shows this data. Results show that the most valued features are related with new experiences of students revealing that campus visits exploring games and AR are activities valued by the target public.

Graph 2. Students' preferences regarding the EduPARK app

The second question on the questionnaire, "What did you think about the value of the EduPARK app for learning about nature conservation?" was divided into eight topics. To answer it, students filled in a table with a Likert scale numbered from 1 to 5 with a degree of agreement (strongly disagree, disagree, neutral, agree, strongly agree). Results are presented in graph 3.

The majority of students felt motivated to learn during the game (11 students "strongly agree" and 6 "agree") and indicated that they had fun while learning with the app (8 students "strongly agree" and 9 "agree"). The majority also indicated that they enjoyed learning curiosities about the city of Aveiro (12 students "strongly agree" and 5 "agree") and felt more capable of conserving nature (9 students "strongly agree" and 7 "agree"). Most students indicated that learning outdoor helped them to better understand the school contents (6 students "strongly agree" and 9 "agree"). Regarding the topic "I will quickly forget what I learned from this app", the majority of students "strongly disagree" (8 students) or "disagree" (8 students) about it. Concerning the topic "Sometimes I answered randomly", most students "strongly disagree" (9 students) or "disagree" (7 students) about it.

The majority of the students indicated that they "strongly disagreed" (9 students) and "disagreed" (7 students) with the item that the app presented confused and difficult to understand information.



Graph 3. Students' opinion about "What did you think about the value of the EduPARK app for learning about nature conservation?"

An overall view about the answers to those topics indicates that students considered the EduPARK app has a positive potential on learning about nature conservation. Students also pointed out that the outdoor context promoted a better understanding of the school's contents. They also indicated that using the app, promoted enjoyment and motivation during the learning activities in the UA Campuses.

Students in the third, and last question of the questionnaire had to choose which environmental issue most concerned them (Table 1). Among the options "recycling", "renewable energies", "food waste", and "ocean plastic pollution", "ocean plastic pollution" was the one that most concerned them (13 students). Ten students justified their choice with two main reasons: a) Relevance of the topic because it is one of the biggest

environmental problems, mentioned by 10 students; and b) Integration in schools' curriculum, as this is a topic rarely discussed in schools, mentioned by 3 students.

About the first sub-category, students said that their generation will have to deal with the consequences of these environmental problems in the future. In the second sub-category, students demonstrated concern about marine ecosystem pollution and the issues about microplastic and its consequences to humans.

The option "renewable energies" was selected by 5 students. They justified their choice with two main reasons: a) Environmental awareness, as "renewable energies" are a less pollutant option (3 students); and b) Interest of the topic, because they are concerned about having a better world, and mention that the resources are limited (2 students).

Table 1. The environmental issue most concerned participating students

Category	Sub-category	Citations Examples	Frequency	
Ocean plastic pollution	Relevance of the topic	"Our generation will deal with the consequences of this problem in the future"; "in addition to killing the fish, people's food is at risk"; "it's more and more common to see plastic in the sea"	10	13
	Integration in schools' curriculum	"Destroys the habitat of many marine animals, some species are endangered"; we must show the consequences of microplastics to the population".	3	
Renewable energies	Environmental awareness	"Non-renewable resources are polluting and finite"; "we can ride more bikes".	3	5
	The interest in the topic	"To have a better world"; "because resources are limited";	2	

No student mentioned recycling and food waste, as probably these are contents they are most familiar with, when compared to the other two topics (Ocean plastic pollution and Renewable energies), which are more comprehensive and difficult to fully understand. Moreover, pollution issues may be a hot topic and a frequent issue explored by students, not only within the school content but also in their everyday life.

4. CONCLUSION

The EduPARK project developed an innovative interactive mobile AR game to promote authentic interdisciplinary learning in a specific urban park (Pombo & Marques, 2019). This paper summarizes the results of an activity of playing a game of the EduPARK app about Sustainable Development.

This game was implemented during the XPERiMENTA event. Regarding the perception of the EduPARK app the aspects that students valued the most were visiting a University through active methodologies, such as games, and exploring innovative educational technologies, namely AR.

The results of the game showed a good game performance for all groups, as most questions were correctly answered. The game question that induced more difficulties among the students was the one regarding fossilization processes, in which two hypotheses can be raised: 1) the used image requires improvements, to become clearer, and 2) this topic has been studied in previous school years, without further mobilization, so it may be difficult to remember these contents and how to apply them. Students considered the game fun to play, appreciated its features, contents, and curiosities about the city of Aveiro. Students also considered that the EduPARK app promotes motivation for learning because they learn in a fun way while walking outside the classroom.

Students also acknowledged the EduPARK app's potential in the promotion of nature conservation learning. After this activity, they revealed feeling more aware of nature conservation problems, in particular in what concerns ocean plastic pollution.

These arguments are similar to the ones described by Chen (2020), in particular the importance of using AR as a learning tool in context, accompanied by the exploration of multimedia resources, promoting mixed realities as an effective learning environment.

By using the EduPARK app, it's possible to explore Sustainable Development theme from different school subjects, but as a common goal, promoting a global understanding of the topic as advocated by international agencies as UNESCO.

These results are in line with other studies that indicate that mobile apps promote student motivation and the construction of learning (Crompton et al., 2017). Therefore, to answer the research question, evidences were collected pointing that the EduPARK app is an educational app with great potential to promote Education for Sustainable Development in basic education students. Innovative interdisciplinary practices, combined with outdoor activities curricularly integrated and supported by mobile technologies, provided the consolidation of knowledge from different curricular areas in students, and the construction of new learning about Education for Sustainable Development.

As a final note, the EduPARK app is an example of a successful mobile AR game for nature conservation learning (Rodrigues, 2021). The great relevance and innovation of EduPARK are related to cross-subject outdoor learning in formal, informal, and non-formal contexts, supported by mobile technology, in an integrated perspective of Science, Technology, Society, and Innovation. In terms of future work, within the EduCITY project, it is proposed to carry out activities related to education for sustainability, with a greater number of students and teachers, from different school contexts, and the general public, replicating the study and enabling the identification of patterns. Furthermore, it is predicted to conceive several teacher training sessions to collect systematic data about the benefits of using this mobile learning strategy in outdoor settings. It is also intended to complement this study with further research allowing a better understanding about the potentialities of mobile AR games in outdoor environments for learning.

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