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Moving learning into a smart urban park: students' perceptions of the Augmented Reality EduPARK mobile game

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Abstract. The EduPARK game is developed under a game-based learning methodology. It is designed for outdoor learning settings by employing geocaching principles and mobile Augmented Reality technologies. The game aims to develop users' authentic and autonomous learning about diverse interdisciplinary themes in a smart urban park. It integrates learning guides for different target groups of basic education. The purpose of this paper is to present the game prototype development, and its first cycle of refinement, as the study followed a design-based research approach. The game evaluation involved 74 students from two school levels (aged 9-10 and 13-14). They explored and evaluated the game. Participant observation and focus groups were conducted. The evaluation allowed identifying positive characteristics of the game, such as immediate feedback and collaborative dynamics. Some questions included in the learning guides were perceived as difficult to understand and also some features came out to be considered for future improvements.

Keywords: Augmented reality; Mobile learning; Smart urban park; Gamification.

1 Introduction

City parks have the potential to provide learning experiences that not only promote the biodiversity valorisation, but also influence the values, attitudes and actions of visitors [1], as students, teachers and tourists. As students' access to mobile devices, such as laptops, tablets, smartphones and video game consoles, increases in several contexts, the debate around mobile learning and its educational potential becomes more critical [2].

The ubiquity of mobile devices allows extending learning, both in formal and informal settings. When combined with Augmented Reality (AR), it has the potential to move learning to the outdoor setting. This approach may be effective in engaging students and helping them to establish connections with content and to socialize with their peers [3], [4].

A crucial aspect for students during the learning process, apart from the motivational one, is to construct knowledge and move to more complex levels of understanding [2]. Skills such as problem solving, critical, analytical and creative thinking, collaboration, teamwork, digital and communication skills are increasingly required by the labour market, and schools should play a central role in preparing students for the needs of today's society and economy [1].

AR is a technology where real life is enhanced by virtual elements in real time [3]. AR appeals to a constructivist learning paradigm and may be used to improve educational values and diversify learning [4]. Outdoor collaborative learning activities using AR is an approach scarcely found in educational research, hence, little is known about the potential of AR to support teaching and learning in outdoors settings.

Only in recent years have researchers started to define more clearly the advantages and challenges concerning the use of AR for educational purposes [5], [6], [7]. In a recent report, authors point out that AR amplifies access to and interaction with information, hence, creating new learning opportunities for broader understandings [8]. Several other studies [4], [9], [10] suggest that AR enhances students' enjoyment, motivation and interest to learn. For example, a literature review [4] highlights that this type of technology provides immediate feedback and supports autonomous learning, which can have a positive effect on students' motivation and increase their learning performance. Moreover, AR has been shown to be able to reduce cognitive load through the annotation of real world objects and environments as well as to increase long-term memory retention [10], [11]. However, for such affordances to occur, the multimedia material should have curricular and educational relevance [2].

As referred above, AR supported by mobile devices can move learning to outdoor settings, such as Smart Cities (SC). The concept of SC is closely related to using "smart" technology to improve city life. SC should be open to all citizens and enable access to information facilitating citizens' participation, collaboration and transparency at all levels [12], [13].

Studies in SC as a context for learning (smart education) show the potential of the adoption of mobile technologies to generate and collect data for situated games in the city [12], [13], namely in the so called Smart Urban Parks (SUP). SUP are based on mobile learning frameworks, i.e. on anywhere and anytime personalized learning [14], fostering learning outside of the classroom into the learner's environments (real and virtual), becoming more situated, personal, collaborative and lifelong [15], [16].

Smart education can be used to promote new modes of learning in science education, for instance in what concerns environmental education, since the ability to understand ecosystems is enhanced by experiences in real environments [5] that can affect student attitudes about nature [17]. The preservation of the historical and biological heritage from SUP requires educational values from communities, such as conservation attitudes and sustainable lifestyles [18, 19]. Other authors [5] specifically point out the unique affordances of AR, as an "immersive" interface that enables participants to interact with digital information embedded within the physical environment, on the support of this kind of situated learning in environmental science education.

The purpose of this paper is to present the development of the EduPARK game within the first cycle of the app prototype refinement following a design-based research approach. The game evaluation was carried out through a user experience involving students, to collect their perceptions regarding the app-use, namely positive and negative perceptions of the EduPARK game regarding enjoyment and level of difficulty. The study value relies on: i) the originality of the product itself which combines different areas of interest; ii) the emphasis placed on user experience during the first cycle of the game implementation; iii) the added value to educational mobile augmented reality games.

In the following sections, and after a brief contextualisation about educational AR games and the EduPARK project, the game will be briefly described. Then the methodological options will be presented, including the data gathering and analysis processes, as well as the results and their discussion. In the final remarks section, empirical-based recommendations are proposed for the EduPARK game improvement as well as, design principles for AR mobile games.

1.1 Educational AR games

One of the emerging potentials of mobile technologies exploration in educational contexts is related with digital games [20]. Educational games are a unique and emerging field that requires partnerships among game designers, educators, programmers and researchers, willing to collaborate in the design of innovative and motivating learning experiences. Future developments in this area involve evaluating and analyzing game usage data, providing powerful tools on how to create better learning experiences, and developing game-based learning, supported by significant data about the students’ perception and their performance while playing [21], [22]. Additionally, the competition created by games may increase students’ engagement in challenging learning situations and improve their overall sense of enjoyment [23]. On the other hand, when game’s wining conditions require working with other players, collaborative dynamics can also be promoted [22], [24].

As the ease of access to mobile devices such as laptops, tablets, smartphones and game consoles by students increases in many educational contexts [25], the debate around concepts such as Bring Your Own device – BYOD [26], and Mobile Learning [2], and their educational potential, become more acute. One of the emerging potentials of the use of the mentioned devices in educational contexts is the domain of digital games that allow students, in addition to learning about specific contents of the various disciplinary areas, to develop meaningful and contextualized learning while simultaneously gaining experience in the use of digital technologies [20]. Subsequently, educational games are not just games, but a unique and emerging field that works at the intersection of game designers, educators, programmers and researchers, who collaborate in the design of innovative and motivating learning experiences. Over the past 10 years the domain of educational games has grown dramatically, amidst countless successes and failures [21]. According to these authors, future developments in this area involve evaluating and analyzing game usage data for educational purposes, providing powerful tools on how to create better learning experiences, and developing game-based learning supported by significant data about the student, and their performance while playing [21, 27].

There are already a number of developed AR games for mobile devices that support authentic learning in outdoor settings, such as the ones briefly described below. A trend seems to be the use of AR apps with some sort of geo-location mechanisms.

Alien contact!, developed by [28] is a curriculum relevant and narrative-driven, inquiry-based AR simulation. In this game, students move around a physical location to get closer to digital artefacts displayed in a map, triggering video, audio, and text files. Students in the same group play different roles and share information to successfully discover why the aliens have landed and solve academic challenges (subtasks involving math, language, arts, and scientific literacy skills). According to [28], this game promotes high engagement and motivation supported by the novelty of the use of handheld computers and GPS to learn; the collection of data outside the classroom (more authentic learning environment); the development of physical space orientation skills; and distributed knowledge, positive interdependence and different roles. The main difficulties pointed out were the GPS errors; screen visualization and audio listening in the outdoors; the high management requirements for teachers (to maintain the activity flowing); student cognitive overload and strong competition between teams.

The AR butterfly ecological learning system [29], developed using AR and mobile technologies, follows a game-based and mobile learning approach to teach students about butterfly species, ecology and conservation, in a campus environment. The AR is triggered by GPS coordinates (location-based AR), so that students can observe virtual butterflies around nectar plants when they approach certain locations. The application also allows the breeding of virtual butterflies to enable observation of the butterfly life cycle and support understanding of their growing process. Students can autonomously use this application.

The EcoMOBILE [5] is another project that combines mobile platforms and AR to provide a more interactive way to learn in outdoor contexts and increase student motivation and engagement. In EcoMOBILE the information is accessed by GPS triggers. The information ranges from interactive media, such as images, videos, 3D models and collaborative quizzes (multiple choice and open-ended questions) to AR visualizations. The authors claim that the use of these technologies keeps students motivated and allows them to explore the field at their own pace, freeing teachers to act as facilitators and move around to check the progress of the different groups. Although these experiences have a lot of positive aspects, an issue found was that some groups just speeded through the activity without reading or fully understanding the contents.

The ZooEduGuide [30] is a mobile application to enhance the zoo visits experience in Thailand. This app provides an interactive way to explore a zoo by combining mobile devices and AR. It has three main modes: (i) learning, which presents information about the animals via rich interactive multimedia content, where the information is accessed by scanning QR codes; (ii) educational games, animal sound identification and trivia quiz, where the game scores are ranked adding a social and competitive component; and (iii) the visit zoo mode, which is a zoo guide where visitors can visualize the map and customize it with their own points of interest and visit path, and check the event schedule. The application makes use of AR to guide the visitor inside the zoo by showing points of interest in the camera view.

The AR competitive game developed by [23] is based on the traditional board game concept. The players need to roll a digital dice, but in this game they move around in a butterfly garden. At each location, students need to answer questions or complete a mini-game. The authors [23] recommend a three-step design procedure for applying a competitive gaming approach to AR-based outdoor activities: (1) select the activities that require students to explore or make observations in real-world contexts; (2) prepare a set of questions related to the real-world contexts for the competitive game; and (3) determine the location and content for each AR-based events.

Overall, the above-mentioned initiatives provide important insights into the use of AR mobile games in outdoor educational settings. For example, AR is recognized as a technology that might enhance student interest and motivation, as well as promote self-learning. AR can support the understanding of complex and abstract concepts and, when combined with game-based learning, students may be more willing to overcome challenges and learning difficulties.

1.2 The EduPARK project

The EduPARK project (http://edupark.web.ua.pt) big challenge is to create original, attractive and effective strategies for interdisciplinary learning in Science through the creation of an interactive mobile Augmented Reality (AR) application, using mobile devices. This is supported by geocaching activities by hunting treasures/caches with the support of the mobile app.

The project aims to contribute to the SUP concept by designing, implementing and evaluating the EduPARK game, supported by a mobile app, to promote learning within an urban park located in Aveiro – 'Parque Infante D. Pedro' that serves as the "lungs of the city" and presents a rich botanical diversity and historical patrimony [1]. The EduPARK game intends to enable teachers, students and the general public to explore and access information about the plant species living in the city park, historical references, different multimedia contents and a map of the park allowing people's interaction [1].The game includes several learning guides for different target groups (students, teachers and, also, tourists), integrating multidisciplinary issues under the Portuguese National Education Curriculum, and proposing interdisciplinary questions and educational challenges so that visitors can enjoy a healthy walk while learning.

In summary, the innovation of the EduPARK project relies on the articulation of the following components: (i) the use of a new and easy to explore AR mobile gamelike application; (ii) geocaching-based learning in outdoor environments; and (iii) interdisciplinary educational materials (guides) [27]. The EduPARK game was tested in the above-mentioned SUP, in order to gather students' perceptions of the game as a means to improve it. The project methodology follows a design-based research approach and this paper reports the implementation and evaluation phase [31–33] of the first cycle.

2 The EduPARK game

As the focus of the EduPARK project is the development of a learning intervention in a real educational context, involving multiple iterations for refinement and evolution of a mobile AR game, a design-based research approach was considered suitable [31-33]. This approach includes two or more cycles of four phases: 1. analyze the problem; 2. design and develop potential solutions; 3. implement and evaluate; and 4. reflect and report [32]. The present paper reports the first cycle of the EduPARK game prototype.

2.1 Analysis of the problem

The EduPARK game was designed to be played at a specific geographic context: the urban park ‘Infante D. Pedro’ in Aveiro, Portugal. This is a large green area inside the city, created in 1862 by Manuel Firmino Maia, who was the president of the city [1]. This park integrates several specimens of tropical (e.g. *Jacaranda mimosifolia*) and native (e.g. *Quercus robur*) flora [1], as well as an artificial lake with some fauna diversity (e.g. *Anas platyrhynchos*). Biological and historical patrimony of this park prompted several teaching and learning opportunities that the research team identified as worth of exploring [1]. This SUP has an important educational potential to develop formal and informal teaching activities about ecological conservation and biodiversity, not only for school education (from basic to higher education), but also for the public in general and tourists visiting the park.

Focusing Basic Education students, which are the target-public of this study, the use of new interactive technologies may provide an opportunity for students to be physically engaged in task solving [17], experience biodiversity in nature and value the protection of green spaces. This might promote an active participation of students, constructing their knowledge, as well as the development of values enhancing an authentic, sustainable and engaging learning [16]. Furthermore, the development of virtual infrastructures closely integrated with the physical landscape, allows to place students at the centre of increasingly ubiquitous educational contexts [12]. This approach fosters authentic and situated learning outside the classroom [15].

Given the potential of mobile technologies articulated with gamification principles and outdoor settings, the EduPARK game was developed combining these aspects and also integrating curriculum content in authentic learning situations, fostering personal and collaborative learning within a lifelong perspective.

2.2 Design and development of the EduPARK game

A multidisciplinary team has been involved in this phase of the EduPARK game prototype. Three Science Education researchers and one Basic Education (BE) teacher collaborated with three Computing researchers in order to articulate the scientific content regarding the city park, the pedagogical activities to be explored and the technical issues of the app.

The EduPARK game provides activities that combine AR and geocaching principles (e.g., finding strategically placed caches) in a SUP, supported by a mobile app. Its first version, developed between September and November 2016, comprised an interactive AR quiz-based game to be played by teams of students, in a friendly competition approach. As such, two quiz-based educational guides were developed:

one for the 1st Cycle of Basic Education (BE) System (9/10 years-old) and another for the 3rd Cycle (13/14 years-old).

The mobile application, for Android devices, was developed using Unity 5, a popular cross-platform game engine. As for the AR marker detection the Vuforia SDK for Unity was used, since Vuforia is currently the most widely adopted platform for AR technology [27]. The basic structure and functionalities of the developed prototype are showed in Fig. 1 and described below.

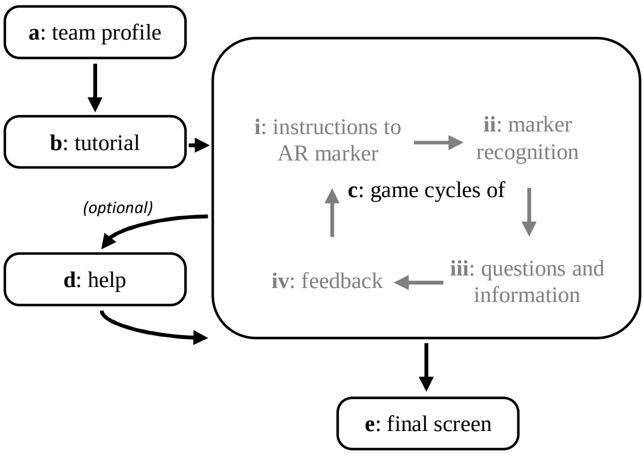
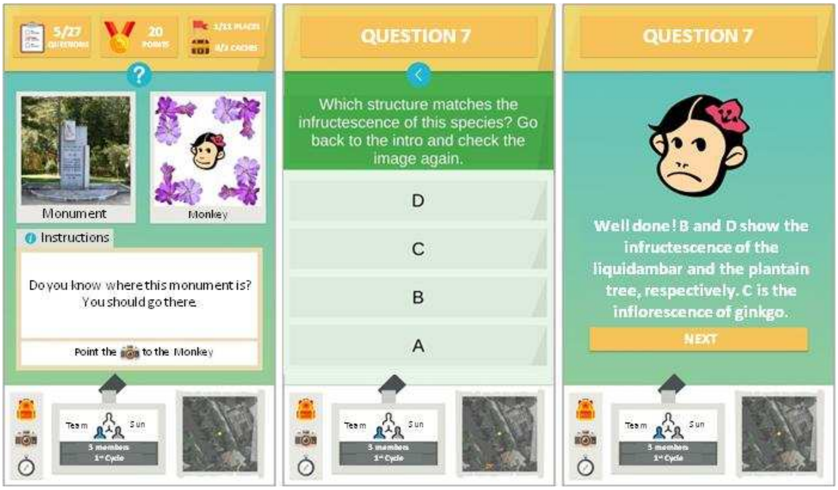


Fig. 1. Structure of the EduPARK app

One of the initial screens of the app prompts the players to identify their team and select a learning guide (step a in Fig. 1): one for 1st Cycle students (aged 9-10) and the other for 3rd Cycle ones (aged 13-14), both of Basic Education. The quiz questions, as well as the predefined path in the SUP, are different depending on the selected guide. A short tutorial follows (step b in Fig. 1) explaining how to use the camera tool to recognize the AR markers. These unlock the access to information relevant to answer a series of questions related to each specific location. Next, the players can initiate the game cycles (step c in Fig. 1): i) following instructions to find a specific AR marker (Fig. 2a); ii) using the device to recognize the prompted marker; iii) accessing a set of multiple-answer questions (Fig. 2b), with associated content; and iv) receiving adequate feedback to answers (Fig. 2c) and points, if answered correctly. The app also provides feedback through the constant display of accumulated points and offers a sense of progress through the number of questions answered, locations visited and caches discovered vs. the total number of these items. The app integrated the hunting of three physical caches/treasures strategically distributed in the SUP.



a) **b)** **c)**

Fig. 2. Screenshots of the app with: a) instructions to an AR marker; b) multiple-answer question; and c) feedback to answer

To support the players' progress, the app provides a number of tools: camera (to recognize AR markers and take pictures), backpack (to see the pictures taken), compass (to support the players' orientation in the park) and a map of the park (with the players' location as well as the next location or cache to visit).

At any time, the players can access the help menu. It has a general help screen and one help screen for each tool. Finally, the last screen displays the overall performance of the team, with the total number of points, the number of correct and wrong answers and the completion time of the game.

The inspiration for the EduPARK mascot was the informal name of the park, known as "Monkey Park". The origin of the name is linked to a female monkey that lived in the park, for several decades. The mascot is being used in the app to guide the players and give them formative feedback after answering one of the quiz questions. For example, when an incorrect answer is given, the mascot provides the right answer, giving a full explanation.

2.3 Implementation and evaluation of the EduPARK game

The first version of the game was designed to be played by teams of students, in a friendly competition approach during the Science and Technology Open Week of the University of Aveiro and was tested between September and November 2016.

Educational guides for the 1st and 3rd Cycles of BE were developed to be played by teams of students, who were prompted to search for and locate three physical caches in the park, in a friendly competition approach [22]. The main purpose was to gather students' feedback to improve the EduPARK game, after playing the game in the SUP. As the guides developed firstly targeted students from the 1st and 3rd Cycles of

BE, registrations for one class from both cycles were open under the Open Week. During the registration period, two teachers, hence two classes from the 1st Cycle, showed strong interest in participating. As a result, this experience was held with two classes of the 1st Cycle and one class of the 3rd Cycle of BE (Fig. 3), from two neighbouring schools of the city park.

Fig. 3. Students exploring the EduPARK game in an outdoor environment.

Detailed information on the implementation and evaluation of the game, particularly on the activity developed during the Open Week, is provided in section 3.

2.4 Reflecting and reporting

The phase of reflecting and reporting is related to the implementation and evaluation of the EduPARK game that will be presented in sections 4 and 5. The analysis of main data aims to identify and discuss positive and negative aspects, as well as enhancement suggestions emerging from the empirical data. The results their discussion and report will be crucial to the next cycle of refinement of the game, as the project follows a methodology with multiple iterations for improvement and evolution of a prototype. The methodological options are described below in the next section.

3 Methodological options to implement and evaluate the game

The present study focuses on the first cycle of the design-based research approach [31–33] employed in the EduPARK game presented previously, comprising several cycles of the prototype refinement, based on the users' perceptions. In the first refinement cycle, the app was tested in three sessions with around 25 students each (Table 1). The total number of students participating in these sessions was 74. Their characterization is showed below.

Table 1. Characterization of the classes involved in the evaluation of the EduPARK game.

Group	Cycle	N. of students	Average age	% of female	% of male
1	1st	26	9,0	69,2	30,8
2	1st	26	9,0	50,0	50,0
3	3rd	22	12,9	31,8	68,2

The participants' personal profile was the following: in the two first groups the average age of students was 9 (students attending the 1st cycle) and 13 in the third group (students attending the 3rd cycle); the majority of participants were female in group 1 and male in group 3. In the second group the gender percentage was equal (male-female).

Before the beginning of the evaluation process, the research team briefed the students about the activity and instructed on how to use the app. Teams of three/four students were established and each team received a mobile device with the app installed. Each team was also accompanied by a researcher during the activity, both for safety reasons and for participant observation of app-play behaviour. Hereinafter, these researchers will be designated as observers.

As shown in Table 2, the evaluation of the app was implemented during two data collection moments: in the first moment – while the game was being played – data was collected through participant observation by the researcher that accompanied each team; in the second moment – after playing the game – data was collected resorting to a focus group interview carried out with sub-groups of students. The interviews were conducted by two researchers.

Table 2**.** Data collection moments during the app evaluation process.

Participants			Evaluation of process				
			During game play			After playing the game	
Session 1	Group 1 (26 students)	1st cycle	7 teams (3/4 students)	Participant observation	Observation grid	2 focus groups (13 students)	Focus group interview guide
Session 2	Group 2 (26 students)	1st cycle	8 teams (3/4 students)	Participant observation		2 focus groups (13 students)	
Session 3	Group 3 (22 students)	3rd cycle	7 teams (3/4 students)	Participant observation		2 focus groups (11 students)	

Participant observation is an acknowledged data collection technique that involves the detailed description of situations, facts, environments, etc. [34]. In this study, during the game play, an observation grid was used to register students' behaviour, especially those that would relate with either problematic or positive events, as well as critical incidents report.

Focus groups are useful data collection tools for pilot tests in educational research (e.g., software development), as they allow interviewees to explain participants experience in depth [35]. At the end of the game play, in each session, two structured focus groups were conducted to collect students' perspectives. In total 6 focus groups were conducted: two comprised 11 students (3rd cycle) and four comprised 13 (1st cycle). Students participating in each focus group belonged to the same class and school, and were, therefore, familiar to each other. This aspect ensured some level of trust among interviewees and facilitated more open responses [35]. The focus groups were audiotaped and moderated with some flexibility and, thus, their duration varied from about 8 to 21 min., with an average of 15 min.

The focus group interview guide combined open and closed-ended questions in order to maximize data collection, regarding the app-use experience. Students were asked to: i) classify their enjoyment of the experience (on a 1 to 5 scale) and point out the reasons for their decision; ii) classify the completion easiness of the activity (on a

1 to 5 scale) and point out the reasons for their decision; iii) propose changes and recommendations for further improvement; and iv) explain their overall sense of the experience. There was an intentional progression from general initial questions to detailed ones and ending with a question to capture the students' overall opinion. As recommended in the literature [35], the researchers paid attention to the number of questions and language used, especially considering the young age of the interviewees.

Observation reports and transcripts from the focus groups were submitted to content analysis [34, 36] with the aim to uncover the appreciated features of the app and the ones needing improvement. The categories emerged from the empirical data and are described in the next section. Data triangulation from the focus groups and from the observations made was also performed in order to ensure trustworthy results [34, 36].

The next section presents the results of the first cycle of the EduPARK game prototype and discusses them accordingly to the literature reviewed. The anecdotal evidence collected suggested some improvement changes, which will be presented.

4 Results and discussion

Data collection gathered from participants (focus groups) and from observations was both broad and specific, leading to concrete suggestions for improving the experience of using the EduPARK game *in loco*. Positive and negative perceptions of the EduPARK game are presented by categories, namely regarding enjoyment and level of difficulty. Content analysis also allowed identifying improvement suggestions for the development of further versions of the game, which are described below.

4.1 Positive perceptions of enjoyment

First, students were asked to classify the activity using a scale, in which 1 stood for lower enjoyment and 5 for higher enjoyment. The answers revealed that in all focus groups, except one, the classification was 5. This implies that the activity was well rated by the students. This result is in line with studies mentioned before that point that AR tools promote students enjoyment [5, 10, 11]. Justifications provided by the students were diverse, ranging from perceptions that could imply the motivational value of the activity to the valorisation of the outdoor activities. In the following paragraphs we describe students' justifications, illustrating them with examples.

The first subcategory is related with 'increased motivation', as illustrated by these citations: "The activity was enriching because it helped us to develop values and helped us to wish for more learning …" (G3 student) and "Students said this activity is really fun and cool" (G2, Observer H). This result is in line with the literature that reports that AR and digital games can promote motivation [3, 4, 9, 10].

Students valued several aspects of the activity. Among them is the 'valorisation of the social aspect of the activity' as mentioned by two students: "I liked it because we are socializing with our friends" (G1 student). Those results are similar to those of [25] that reports socialization with peers as one of the advantages of AR technology.

Another aspect was related with ‘valorisation of the outdoor activity’: “I think we can achieve better results outside the classroom, because we are in physical and visual contact with the content we are supposed to learn” (G3 student) and “nature is really everywhere” [student citation] (G1, Observer C). The possibility to establish connections with content was also reported by [25] and it was acknowledged to support situated and authentic learning [15] , [20].

‘Valorisation of SUP related content’ was expressed by the students, as well as by the observers’ notes, in the following citations: “The activity was important because we learnt more about the park” (G1 student) or “Students enjoyed learning about the park” (G1, Observer C).

Students also pointed to the ‘valorisation of the learning pace’, as the citation shows: “… we learn quicker” (G3 student), and to the ‘valorisation of the immediate feedback’ on the correct and incorrect answers included in the EduPARK game. For instance, one student stated: “I enjoyed it; because if we answered wrongly, the correct answer would show and we could learn more” (G2 student). The immediate feedback is related with increased learning performance [4]. This feature provides an individualized learning strategy to heterogeneous groups of students, giving an extra scientific explanation of the learning content activities integrated in the interactive quiz-based game. This is also one of the reported advantages of AR technologies in the literature, one that can promote autonomy [4].

4.1 Negative perceptions of enjoyment

As described above, the majority of the students pointed out positive features of the activity, but they did not provide negative justifications. Nevertheless, some students highlighted some negative aspects of the activity related with the level of difficulty, which are presented below.

4.2 Positive perceptions of the level of difficulty

Concerning the level of difficulty, the students’ perceptions were rated between 4 and 5. Two groups did not justify their classification. The ones who did provided the following justifications.

‘Connection with the curricular content’ was one reason that students pointed out for considering the activity easy, as illustrated by the citations: “As we already knew the content, it was easier” (G1 student) or “Students stated that they already knew the information about the European holly [*Ilex aquifolium*]” (G2, Observer F). This result is in line with some authors’ recommendation concerning AR activities that they should be educationally relevant for students [6] and contextualized, which seems to be the case of the EduPARK activities.

‘Problem solving strategies’ were identified by several observers that stated, for instance, that: “[Initially] students needed our help, but then they became more autonomous in solving problems” (G2, Observer G).

‘Instruction adequacy’ was also pointed by the observers, who mentioned: “Students easily understood when they had to move to another location” (G3, Observer I).

4.3 Negative perceptions of the level of difficulty

Students justified their lower rates concerning the level of difficulty of the EduPARK game referring to specific challenging aspects. One of the aspects is related to ‘difficulties to interpret the questions’, for instance related with the location of a specific object [bird in the roof] (G1 student) or inobservance of specific signs [locate the dates 1931 and 1932 in a panel of tiles] (G2, Observer F). Another type of difficulties, related to the interpretation of questions, is concerned with the ‘difficulties with the vocabulary’, which were observed especially in the younger groups: “Students didn’t know the meaning of ‘fertilizer’ and ‘honouring’” (G2, Observer F) or “Students didn’t know what plans of symmetry were” (G1, Observer E).

Concerning the ‘location of the AR marker’, students apparently had different views. Some considered them too easy to find: “I believe they should be physically better hidden [referring to the markers]” (G3 student); an observer registered that “For them [another team] it was easier, because they didn’t have to look for [the marker]” (G1, Observer C). Those who considered the markers were difficult to discover remarked that “The last one [marker] was really hard to find” (G3 student) or “The students didn’t find the second treasure [third marker] by themselves” (G1, Observer E). Geocaching aspects of the game were also pointed out by the observers. For example: “Students didn’t understand how to use the compass” (G2, Observer F) or “Students didn’t find the right direction” (G1, Observer E).

Finally, some students reported ‘difficulties with cultural questions’: “I do not feel at ease with this kind of questions [culture questions]” (G3 student) or “Students found the general culture questions difficult” (G2, Observer F). Although some content of the AR game was familiar to students, as it was related with the curriculum, their knowledge about the local history and culture of Aveiro seems to be scarce, regardless their age.

4.4 Improvement suggestions

Students’ improvement suggestions were spontaneously made during the activity (and registered by the observers) and prompted during the focus groups. They were related with three subcategories: i) dynamic of the activity, ii) types of questions, and iii) interest of the activity.

Concerning the dynamic of the activity, several subcategories emerged. For example, students’ opinions about the ‘teams’ constitution’ were not consensual, as some of them preferred to work in smaller groups: “I think it would be better to play in teams of only two or three students” (G1 student), and others favoured bigger teams, since “Maybe playing in bigger teams, because [more elements] can think better” (G3 student). These contrasting opinions can be related to differences between students’ ages (9-10 and 13-14). Nevertheless, one of students’ concerns was related with the collaboration level within the team, which may be created in gaming situations, as claimed by [15].

The youngest students proposed to ‘extend the activity’: “I think the activity should have more questions and cover more places in the park” (G1 student) and “I wanted this activity to last longer” [student citation] (G1, Observer F). This fact may be associated with a stronger level of enjoyment with the activity reported by the youngest students (who classified the activity with 5 points).

The following subcategories are related with students' suggestions for designing other types of questions for the game. In order to improve the game, students proposed to include 'more subjects' in the learning guide, such as Portuguese, English, Astronomy, and Sports, as well as to comprise more 'diverse questions'. While one student said that "We would like to have more questions like the one involving the calculus …" (G1 student); another suggested a new type of question, based on visual recognition: "I would like to be asked to go to a known location" (G1 student).

Students provided valuable hints to increase the interest of the activity related to the inclusion of 'different paths and sites'. For example, students proposed: "… we should have more locations. For instance, I think that we could focus more in the lake, since we have a very beautiful lake [in the park]" (G3 student); "Different paths should be implemented" (G1, Observer B). Another student's suggestion was related with 'preventing cheating behaviour', as expressed in the following citations: "I think that the hints should be different from team to team because, when a team is behind, they can copy what the others are doing" (G1 student) and "Students think that the teams should have staggered starts during the activity" (G1, Observer D).

Finally, students also suggested to 'increase the competition', as revealed by these citations: "We could take a photo nearby the caches and then, the best photo would be the winner" (G2 student) and "One of the criterions [to win] should be the time, to increase the competition" (G3 student).

5 Final remarks

The development of the EduPARK AR game follows a design-based research approach [31, 32]. In this work we present the implementation and evaluation phase of the first refinement cycle. The game was experienced by students in a SUP, the "Infante D. Pedro" park in Aveiro (Portugal). Data gathering techniques included focus groups (with students) and observation. The authors acknowledge some limitations, such as the loss of participants' nonverbal cues, as the interviews were audiotaped and not videotaped. Another aspect to consider is the fact that students were interviewed in a group, which has the potential to standardize the participants' opinions [24]. However, given the available resources and setting for the conduction of the interviews, these limitations may not affect the results, taking into account that the aim of this work is to collect the players' opinions regarding the activity *in loco*.

Results suggest that students considered the game enjoyable and easy to play. However, some negative perceptions were also pointed out. These results allowed us to propose some design principles, as major contributions to this area of knowledge that can be useful for future educational games in SUP, or similar contexts.

In what concerns gaming aspects, the main goal is to keep the player engaged in learning for a long time, as the game activities should increase students' motivation to learn [2, 4, 9, 10], by providing immediate feedback [4], socialization opportunities among peers [7] and challenging experiences, by balancing the difficulty of the AR markers localization [20].

Games should be as much versatile as possible, according to the inclusion of a rich choice of game elements, such as treasure hunt and multiple choice questions, to enrich the gameplay experience and diversify the overall gameplay experience, as the main goal is to keep the player engaged in learning for a sufficiently long time [24]. On the other hand, the game should also provide versatility of users, allowing to be played individually or in groups to promote social interaction and negotiation of understandings [15].

It is also important to provide adequate instructions, by attending to eventual difficulties to interpret the game questions and using suitable vocabulary, as this was a specific users' comment to improve the next app versions.

Concerning pedagogical issues, games should be explicitly grounded by learning theories, such as situated learning, authentic learning and constructivist learning theories within local and contextualized environments [15], [16], Furthermore, it is important to take advantage of the outdoor contexts, e.g. SUP, to promote situated learning, allowing contact with nature, local culture and history issues, to promote learning at a faster pace than in the classroom and increase learning performance [4].

Other important aspect is the inclusion of interdisciplinary contents based on the curriculum [7] to increase learning opportunities, such as problem solving strategies, autonomous learning and other soft skills. Finally, choosing technologies that students are familiar with, such as mobile devices that are usually used in out-of-school contexts, facilitate the users' experience, game engagement and learning.

The above-mentioned design principles may contribute to create better learning experiences, supported by significant data retrieval from students' perceptions and their performance while playing [21]. Students' offered several relevant improvement suggestions such as: increase the length of the activity, provide different paths and sites in the SUP, increase competition to promote enjoyment and learning [20] while enabling collaboration [21], and diversify the type of questions and of curricular disciplines involved. These suggestions will be considered in future work under the EduPARK project.

The results show that combining mobile technology with outdoor gaming activities allows learning to move beyond traditional classroom environments that students can explore and, simultaneously, make connections with curricular content. Furthermore, the EduPARK AR game provides collaborative, situated and authentic learning. It also offers new challenges, opens up horizons and opportunities for Science Education. The EduPARK game already integrates some of these recommendations [dynamic of the activity, types of questions, and interest of the activity], because the EduPARK researchers recognize that the game competition is an important aspect for promoting enjoyment and learning in students [23]. In line with [1] it is also acknowledged that the Aveiro SUP has important educational potential to develop formal and informal learning about ecological conservation, biodiversity and city historical patrimony, which will be reinforced in future versions of the EduPARK game.

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