Learning with the Augmented Reality EduPARK Game-Like App: Its Usability and Educational Value for Primary Education

Lúcia Pombo(✉) and Margarida M. Marques

Research Centre on Didactics and Technology in the Education of Trainers (CIDTFF), Department of Education and Psychology, University of Aveiro, 3810-193 Aveiro, Portugal
{lpombo,marg.marq}@ua.pt

Abstract. The EduPARK is a research and development project that intends to promote interdisciplinary mobile learning, supported by the development of an application to be used in an urban park, providing students' involvement, motivation and engagement to enhance authentic and contextualized learning. The EduPARK project follows a qualitative interpretative methodology fitting in a design-based research, a useful framework for developing technology-enhanced learning resources comprising various cycles of prototype refinement: a game-like app for mobile devices, with Augmented Reality (AR) contents that follows geocaching principles. After those refinement stages, the final version of the app was released for the public in the Google Play Store; and around 50 activities were organized to collect systematic data to better understand mobile learning in outdoor settings, not only in formal but also in non- and informal contexts. To date, EduPARK has involved about 800 students from primary to higher education, 200 teachers and 60 tourists; however, this paper reports a survey study focused particularly on data of participants attending the first four years of primary education. A total of 290 students, organized in 73 teams, completed the game and expressed their opinion about the usability and the educational value of the app in a questionnaire applied after the activity; and automatic app loggings were collected. Results show that the EduPARK app achieved a good usability and has educational value for primary education students. The present work proposes a data collection tool, inspired in Brooke's instrument, regarding the educational value of a game-based mobile AR resource.

AQ1

Keywords: Mobile learning · Augmented reality · Outdoor activities · Game-based learning · Authentic learning

1 Introduction

Traditional classrooms are often described as teacher and textbook centered with students playing a passive role in learning. In traditional classrooms pupils are asked to turn off their mobile devices, which usually accompany them everywhere, before initiating the learning activities. This denotes a big gap between the use of mobile

K. Arai et al. (Eds.): CompCom 2019, AISC 997, pp. 1–13, 2019.
https://doi.org/10.1007/978-3-030-22871-2_9

devices inside and outside school that can lead to students' disengagement with learning activities, thus, impacting negatively their academic success [1]. Yet, at least in educational research related contexts, mobile devices can be easily incorporated in primary education classrooms and have learning potential when used in dynamic, collaborative and interdisciplinary activities in classroom environment [2]. These authors pointed gains on student attention, motivation and classroom climate, as well as an improvement in the development of students' key competencies.

The EduPARK project (http://edupark.web.ua.pt/) aims to promote interdisciplinary learning using mobile devices, augmented reality (AR) and games based on geocaching principles, in outdoor environments, particularly in an urban park, the Infante D. Pedro Park, in Aveiro - Portugal. For that purpose, the project developed a game-like app - the EduPARK app - an interactive application with four educational games, articulated with the national *curriculum*, for specific audiences: teachers, students from basic to higher education, and also by tourists/public in general in a lifelong learning perspective. In collaboration with Aveiro City Council, plant identification plaques were installed in the urban park with AR markers that trigger information in images, audios, videos, schemes, and interactive 3D plant leaves. That information was overlaid on top of a real-time camera feed of a feature within the park, augmenting the reality. Tiles, already located in the park, are also used as AR markers to augment information about historical and regional issues and virtual treasures can be found along the game both in plaques or in tiles [3]. The EduPARK app was developed through a design-based research with four development and refinement cycles that involved the app evaluation, *in loco*, by students and teachers [4]. The app is now freely available for Android devices, in the Google Play Store (http://edupark.web.ua.pt/app).

The EduPARK project organized about 50 sessions of park exploration with the EduPARK app, involving more than 800 students, 200 teachers and 60 visitors. In these sessions, players walked in the Park using mobile devices with the app installed, and followed the instructions of the project's mascot to experience the AR available in several interest points.

The main relevance of the project is its innovation in terms of outdoor learning strategies, in formal, informal and non-formal contexts, in an interdisciplinary way, combining it with technology. This will allow learning to move beyond traditional classroom environments to nature spaces that students can physically explore at the same time that they make connections with curricular contents. The project promotes articulation between research, teachers, professional practices, and initial and advanced training, constituting a very useful theoretical and practical framework, with impact not only in schools, but also in the community and in the tourism sector.

The purpose of the paper is to present a survey study that analyzes the usability and the educational value of the app focusing primary education data (6 to 10 years old pupils) with the overall goal of proposing methodologies of mobile learning in primary education schools. The rest of the paper contents: (i) addresses some keywords related to this approach, such as mobile learning, augmented reality, geocaching, outdoor activities, game-based learning, and authentic learning; (ii) briefly presents the EduPARK app, in what concerns its development process, its unique combination of innovative features, and game structure and mechanics, so the reader can have a concrete idea of this mobile learning approach; (iii) describes the methodology of the

study; (iv) presents and discusses the main results; and (v) brings forward the core conclusions, limitations and the main contributions of this paper.

2 Theoretical Context

Mobile learning refers to a way of learning that comprises social and content interactions, supported by mobile devices such as smartphones or tablets, and, hence, it can occur across physical locations and educational contexts [5]. These devices are small and light enough to be easily carried to different places [6], support interactivity with others and with media content [7] and allow a high variety of contextual and situated learning activities, trough the proliferation of hardware and applications [8]. However, mobile learning may entrench digital divides regarding technology access, technological skills and learning competencies [8] and it requires an high preparation from teachers [6], who may not be tech-savvy. Nevertheless, it may be worthwhile to develop mobile teaching strategies, as the literature accumulated evidence that learners using a mobile device reached higher cognitive achievements than those not using these devices, particularly on kindergarten and elementary levels, and their affective learning outcomes also seem to be enhanced [6].

The dissemination of mobile devices allows the public to have access to Augmented Reality (AR) systems [9]. It is a technology that allows overlapping virtual elements (e.g., 3D models) with real objects of the physical world, in real-time, producing a new experience [10, 11]. AR content can be triggered by image recognition or by the user's location (from GPS or wireless network). In educational contexts, AR can make boring learning content more enjoyable, it can be used to provide immediate feedback and support autonomous learning and, thus, it has potential to increase learning performance [12, 13]. Among AR pitfalls are its usability and GPS related technical problems [12]. The GPS technical problems were also identified in the EduPARK during the early stages of app development. That was due of a lack of reliable GPS signal in outdoors with abundant treetops, so the project team decided to use image-based AR technology, with marker-based tracking [14] instead of GPS location-based markers.

The literature claims that mobile learning can also be combined with game-based learning (GBL) to increase the learner motivation, self-directedness, and social and inquiry skills [15]. GBL denotes the use of games to promote knowledge and skills acquisition, whilst providing players/learners with a sense of achievement [16]. Games can be designed to be powerful learning environments, particularly if they activate prior knowledge and offer instant feedback [17]. However, GBL requires careful design to balance the play and the learning outcomes [15] and, if the aimed learning and the game content are not integrated enough, the GBL approach using mobile devices is not likely to be effective [6]. The EduPARK project decided to use geocaching principles to ensure an engaging game play experience to the students. Finding hidden treasures promotes curiosity, which is known to be a powerful intrinsic motivator, as happened very successfully in the Pokémon Go [18].

The use of mobile devices liberates the learner from physical boundaries, beyond the typical classroom, and allows outdoor learning [7]. The literature claims that using

mobile devices to learn in the outdoors and informal locations is more effective than using them in more formal places [6]. According to the literature, authentic learning experiences can be provided by mobile devices [7] and by AR technologies [19]. These technologies can situate the learner in a realistic physical and social context and scaffold learning processes [11]. Authentic learning builds on constructivist learning theories, particularly on situated learning, and includes features such as providing an authentic learning context and collaborative construction of knowledge [20], giving students an active role in learning as they experience and use information in ways that are grounded in reality, instead on memorizing facts in abstract situations.

3 The Game-Like App EduPARK

The creation of a user-friendly mobile game-like app with Augmented Reality (AR) contents on the park's biodiversity and other interdisciplinary information required a close iterative collaboration amongst the members of the project team, which are from different areas and professional contexts: Educational researchers and Science Teachers, Botanic specialists, Computer Science professors, and a Programmer. The Educational specialists identified curriculum related learning opportunities in the park and developed four educational guides for the app, targeting publics from basic to higher education and also for the general public. The Botanic experts identified and described a set of 70 native and exotic species in the Park and provided botanical contents for the AR triggers, giving priority to species with value to curriculum learning and to the promotion of conservation and environmental habits. The Computer Science professors developed the technological aspects of the AR app in an intense dialogue with the Educational experts, in order to define the relevant features to promote motivation and engagement with learning. The programmer technician developed the mobile application, for Android devices, using Unity 5, a popular cross-platform game engine [21]. 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 [22].

The app development fits a design-based research methodology with four cycles of development involving user testing and evaluation. Several field tests were conducted, involving different convenience samples of potential users, from basic to higher education, including pre and in-service teacher training and park visitors in a lifelong learning perspective. The app was progressively refined according to the users' feedback in each cycle, concerning usability and educational value. Those refinements and final version of the EduPARK app are presented in detail in Pombo & Marques [23].

EduPARK app features integrates a set of aims/principles, as addressed by Pombo, Marques, Afonso, Dias & Madeira [24], including: (i) contextualized learning in the park, e.g., related with the botanical species or with the historical monuments in the park; (ii) interdisciplinary learning, e.g., using flowers to address issues about symmetry axis; (iii) recommendation to play in small teams, although it is perfectly playable individually as well, as generally research suggests that collaboration is more effective than competition for reaching achievements, as the app's educational

challenges can promote collaborative discussion of ideas; (iv) the context is successful either in formal (school visits to the park), non-formal (e.g., in environmental education sessions of app use promoted by the local City Council) or informal learning contexts (e.g., a family visiting the park explores it through one of its games/educational guides); (v) user-friendly, so users, even children in primary education, can use it without support of the EduPARK team.

To develop the app it was important to carefully analyze the National Curriculum to identify multidisciplinary issues (e.g., integrating Biology and History or Biology and Math) that might be explored in the selected park. The identified issues were used to create four interdisciplinary educational guides, or quiz games, for the app. From these, three quizzes are intended for different levels of the Portuguese Education System: (i) the 1st Cycle (for 6 to 9 years-old students); (ii) the 2nd (for 10 and 11 years-old students) and 3rd Cycles (for 12 to 14 years-old students) of Basic Education; (iii) the Secondary (for 15 to 18 years-old students) and Higher Education; and (iv) one quiz is intended for any ordinary citizen visiting the city park, the Infante D. Pedro Park.

The Park is a large green area, with exotic and native botanic species, avifauna, a lake and several historical points of interest. It comprises educational value, in what concerns conservation and sustainable attitudes, since the ability to understand ecosystems is boosted by experiences in real environments influencing communities' attitudes about nature [3]. From an analysis of the park's patrimony, several teaching and learning opportunities have emerged and were explored in the educational guides. Additionally, the park spaces, which have physical barriers around most of their perimeters, are well defined safe environments for children to have mobile AR gaming experiences. This is an example of a truly authentic context for situated learning, where the location is essential for the learning [18]. The project has a mascot that is being used in the app to guide the players and give them immediate formative feedback after answering; e.g., when an incorrect answer is given, the mascot explains the right answer. The inspiration for the EduPARK mascot was the park's informal name: 'Monkey's park'. That name's origin is linked to a female monkey that lived in the park, for several decades. The mascot is also available as a physical plush doll, and it rapidly becomes a friendly figure for a 6 to 9 years old child (Fig. 1).

The project planned to promote school visits and other activities in the park for app test and exploration, so it acquired a set of smartphones and tablets to lend to the project's participants.

The game is organized in four stages; each stage corresponds to an area of the park, identified in the app's map (left picture in Fig. 1). In each stage there are a set of questions. Each question has 4 response options. The aim of the game is to gather as many points, bananas and virtual caches/treasures as possible. Points can be gained by answering correctly the questions that are contextualized with certain locations of the park. For that, pupils are invited to visualize AR resources underlying some questions, and try to find out, or to remember, for example, what kind of triangles exist in the Tea House chimney, which is the rock of the bandstand base or what are the reproductive structures of certain botanical species of the park. They are also challenged to find virtual treasures with bananas (Fig. 1) that can be used for extra support with the questions or to gain extra points at the end of the game.

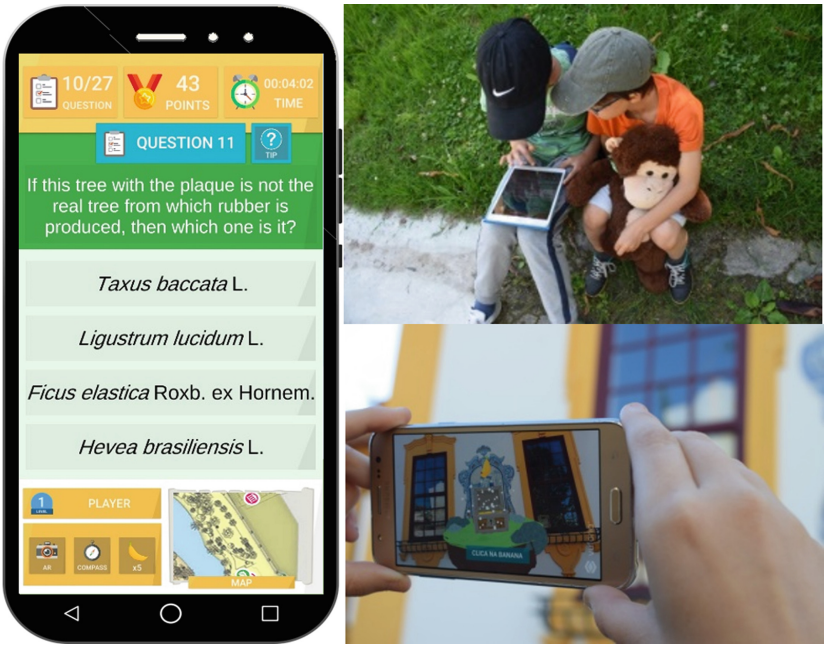

Fig. 1. EduPARK activities with an app's screen (left picture), children playing in group (right top picture) and a virtual treasure displayed on the mobile screen (right bottom picture).

During the game, players can use different tools (Fig. 1 left): (i) AR camera, a tool to recognize the AR markers and to trigger the AR contents; (ii) compass, a tool that supports orientation in the park based on the display of the direction of magnetic north; (iii) bananas, a tool that shows the number of captured bananas and allows to switch bananas for extra help in the quiz questions; and (iv) map, a tool that also supports orientation in the park. In the EduPARK activities, each team of players was accompanied by an adult familiarized with the app and game, for safety reasons.

The EduPARK app game has awakened, systematically, interest and enthusiasm from users, who learn in a fun way while having a healthy walk in the park.

As the park does not have free internet coverage and not all Portuguese mobile device owners have a strong internet coverage service, the team decided to develop the app for offline use. The only requirement for having a mobile device with a fully functional EduPARK app, in an offline mode, is to download the app and its educational guides before going to the park to use it.

In the EduPARK project, the 32 plaques installed in the park have the same layout; however, the information in each one varies accordingly with the botanic specimen: the scientific and common names, its family (in biological classification), its origin and the AR marker, with the project's mascot [14]. The AR content associated with each plaque includes resources about the identified species (texts, photos, videos, 3D models) (Fig. 2).

Fig. 2. The EduPARK app triggering AR content through image recognition (top picture); example of botanic AR content, the leaf can be digitally rotated to show its upper and lower surface (bottom pictures).

4 Methodology

The project EduPARK aims to study how playing a game, supported by an interactive mobile AR app, the EduPARK app, in a specific outdoor context may promote learning and motivation for learning, among other affective gains. At this stage the app is already developed and released for the public in the Google Play Store, therefore, the present paper gives continuity to previous works, such as [14, 24], by reporting a survey study focused on the analysis of the usability and educational value of the EduPARK app for children attending primary education.

Empirical data was gathered throughout the first year of app use in 15 outreach activities organized by the project involving schools and other educational entities with primary education children. Students were organized in teams of two to five members to collaboratively play with the EduPARK app in the Infante D. Pedro Park (Aveiro, Portugal). A total of 290 primary education children, both in formal and non-formal educational contexts, played with the app and participated in this study. Data collection included a questionnaire survey applied immediately after the app use and, also, automatic app logging mechanisms regarding the score attained, number of correct and incorrect answers, etc. Data were collected anonymously and research ethics principles were respected.

The questionnaire comprises four sections, with closed questions: 1 (strongly disagree) to 5 (strongly agree) Likert scale, multi-choice and item selection. Section one was about the perceived usability of the app and it had 10 items based on the 'European Portuguese Validation of the System Usability Scale (SUS)' [25], which is a scale translated for Portuguese from Brooke's [26] original instrument. Individual SUS scores were computed according to Brooke [26], with values varying from 0 to 100. In the present study, scale results were interpreted according to Sauro [27], who reviewed

500 studies and considered 68 to be an average SUS score, and to Bangor, Kortum and Miller [28], who empirically defined a qualitative classification for SUS. The second section gathered data about students' opinion on the educational value of the app. Hence, it included 12 items, carefully defined and revised by two educational researchers, on: (a) the app's learning value; (b) its contribution for intrinsic motivation; (c) engagement; (d) authentic learning; (e) lifelong learning; and (f) conservation and sustainability habits. These items are presented in Table 1. An Educational Value Scale (EVS) was computed in a similar way of the SUS. Section three includes one Likert scale question with one item about the respondents' level of interest regarding the activity of playing an educational game in the park using the EduPARK app. Finally, the fourth section collected basic demographic data (such as age and gender), as well as some information about the children's profile as mobile devices users.

Table 1. Educational Value Scale (EVS) items

EVS item
1. This app helps you learn more about topics we study at school
2. This app shows information in a confusing way
3. I feel motivated to learn when I use this app
4. I do not feel like using this app to learn
5. Even in the difficult quiz-questions, I try to find the right answers
6. Sometimes I respond randomly (without thinking)
7. This app shows real-world information that helps you learn
8. I will quickly forget what I have learnt from this app
9. Park visitors can learn from this app
10. This app promotes learning only in a school context
11. This app makes me feel like talking to others about nature protection
12. This app does not help to realize that it is important to protect nature

The app logging mechanisms were automatically and anonymously collected and include the following information from finished games: (i) number of questions answered correctly and incorrectly; (ii) number of hunted geocaching treasures; (iii) number of bananas collected in the treasures; (iv) final score, including the points gained through the collected bananas; and (v) time of gameplay.

Data from the app loggings and other data from the questionnaires, with the exception of the scales computing, were analyzed through descriptive statistics. These sets of data were triangulated in order to provide a comprehensive knowledge of the usability and educational value of the EduPARK app. This analysis will be presented in the next section.

5 Results and Discussion

This section starts with a brief characterization of this study's participants, followed by an analysis of the EduPARK app usability for primary education children and, finally, the analysis of its educational value.

Data collection allowed gathering information about the profile of primary education children who experienced the EduPARK app under an activity organized by the project during the first year of public implementation. The population age varies from 6 to 10 years old, being 48% of girls and 52% of boys. They all were attending grade one to four (7.6% in grade 1; 26.2% in grade 2; 42.9% in grade 3; and 23.3% in grade 4). The majority of students (74.4%) have Android mobile devices, such as smartphones or tablets. Most students claim they use mobile devices to learn either frequently (26.2%) or sometimes (49.7%); the others (24.1%) did not use them for that purpose at all. According to these results, most of these children are already quite familiar with mobile technologies and are used to employ them for learning. These results seem to support the literature, regarding the proliferation of mobile devices [29], especially in what concerns young population.

5.1 The EduPARK App's Usability

Figure 3 summarizes children's opinion regarding the usability of the EduPARK app. Their perception was positive, as, e.g., 223 students agreed or strongly agreed with the statement 'This app was easy to use' and 172 disagreed or strongly disagreed with the statement 'This app should not be so difficult to use.' SUS score values ranged from 30 to 100, with an average of 76.6, which is an higher value than the average SUS value (68) computed by Sauro (2011). Moreover, according to the classification of Bangor et al. (2009), the EduPARK app achieved a good usability for primary education students.

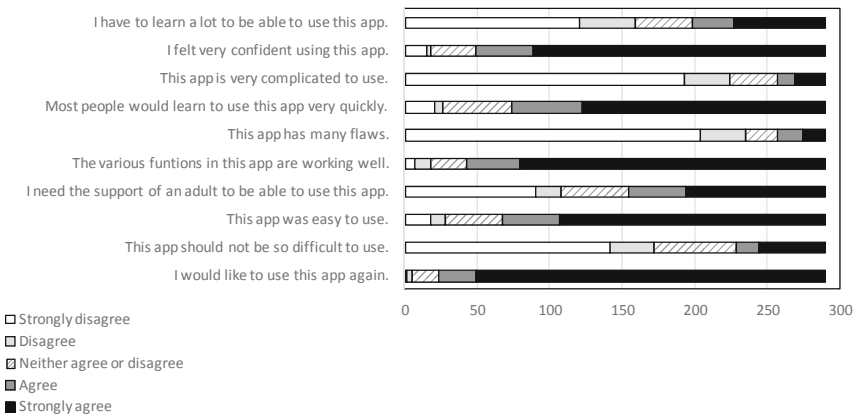

Fig. 3. Primary education students' opinion regarding the usability of the EduPARK app

5.2 The EduPARK App's Educational Value

Almost all the students (95.2%) considered the activity of playing with the EduPARK app in the park for learn very interesting.

Figure 4 summarizes children's opinion regarding the educational value of the EduPARK app. Their perception was positive, as, e.g., 270 students agreed or strongly agreed with the statement 'This app shows real-world information that helps you learn.' and 257 disagreed or strongly disagreed with the statement 'I do not feel like using this app to learn.' EVS score values ranged from 37.5 to 100, with an average of 84.7, which seems to be a high value, although more studies are needed to sustain that claim. Nevertheless, the results seem to reveal that the EduPARK app has educational value for primary education students.

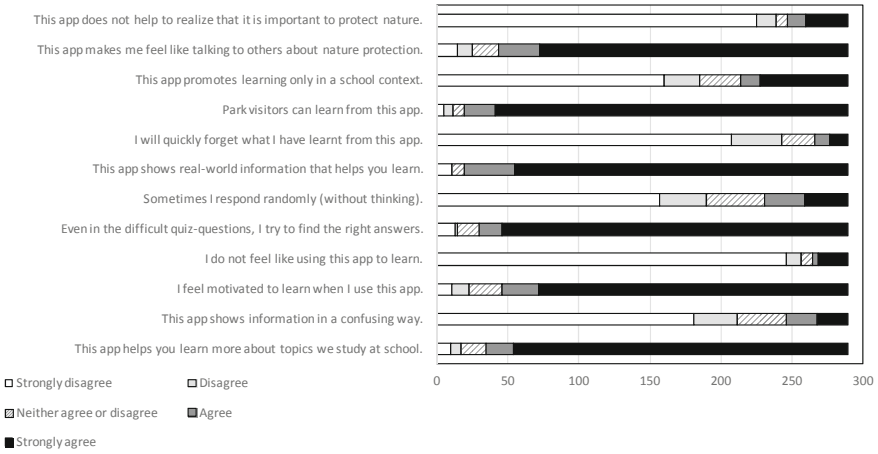

Fig. 4. Primary education students' opinion regarding the educational value of the EduPARK app

Students organized in 73 teams, completed the primary education game during the activities organised by the EduPARK, so the data collected by the app was automatically and anonymously generated from these completed games. These data are presented in Table 2. In 27 quiz-like questions, the young children answered correctly an average of 21.5 questions, with a maximum of 27 correct answers and a minimum of 11. These results reveal that most of the gamers were able to select the right answer of the quiz questions, either because they already knew the answer or because of the adequacy of the app's supporting information. By discovering a maximum of four treasures, players can earn a maximum of 20 bananas (five per treasure), according to how quickly they found them. Data reveals that most players found all the treasures and earned an average of 14.6 bananas, so the treasure hunt tasks were quite accessible to most players. The number of earned bananas, of correctly answered questions and of AR contents accessed are all considered to compute the game final score; data revealed that final scores reached an average of 237.8, maximum of 299 and minimum of 134.

Thus, the results about the children's performance in the game support their views regarding the high educational value of the EduPARK app.

Additionally, the time in game varied from nearly 53 min to 2 h and 8 min, with an average of 1 h and 24 min. This factor did not have impact on the players' scores. The gameplay time showed that students were able to stay commited with the game for long periods having a positive performance in the proposed tasks in the app.

Table 2. Automatic app loggings regarding 73 teams who completed the primary education game

	Number of correct answers (out of 27)	Number of incorrect answers (out of 27)	Number of treasures (out of 4)	Bananas (out of 20)	Final score	Game play time
Average	21.5	5.5	3.8	14.6	237.8	01:24:40
Maximum	27	16	4	19	299	02:08:47
Minimum	11	0	2	3	134	00:52:56

6 Conclusion

The EduPARK project developed an innovative interactive mobile AR game, freely available at Google Play Store, to promote authentic interdisciplinary learning in a specific urban park. This work reports on the first year of implementation of the EduPARK app with 290 primary education students in outdoor activities organized by the project. The focus is the usability and educational value of the app for this school level.

The results point to a good usability [28] and high educational value of the EduPARK app for primary education children, indicating that it is easy to use and promotes authentic learning in this target-public. Hence, resources that combine this set of innovative features, such as being mobile, explorable in the outdoors (namely in urban parks), with contextualized contents, supporting game-based geocaching activities and with AR contents, can be easy to use and may promote learning, both at a cognitive level and at an affective one (such as increased motivation for learning). These features [2, 6, 7, 12, 13, 16, 18] can be successfully integrated in methodologies to teach, in an authentic way, interdisciplinary and contextualized issues to primary education students in informal settings of their communities, such as urban parks.

Limitations of this study are related to the young age of participants. Although using a data collection tool adapted for the age range of the first four years of primary education, the level of excitement related with the timing and set where the questionnaires were applied (just after playing the game and in the park) may have hindered their concentration during the questionnaire filling. Moreover, possible reading difficulties of this target population may also have biased the results. Nevertheless, to reduce the impact of this factor, children were supported by the adults, who accompanied each group, to assure they understood the questions and answer options, whenever needed. Teams' constitution may also have influenced the results, as each student's level of participation in the game decreases as the number of team members

increases. This factor may have impact on how the activity is perceived by the app players. However, this variation in teams' constitution could not be addressed, particularly with activities with a higher number of participants, as it was related with the human resources available to accompany each group of children in each session.

Additionally, the present work presents a new data collection tool, the Educational Value Scale (EVS), regarding the educational value of a game-based mobile resource that was inspired in the well-established SUS instrument [26]. The EVS can be useful both for educators and educational researchers for easily evaluate and compare different innovative resources and make decisions regarding which resources employ in their practice.

Future work under the EduPARK project will involve the study of the usability and educational value of the EduPARK app for other school levels, in order to analyze the potential of the proposed methodology in several formal and non-formal contexts. Finally, more studies of EVS, involving the rating of other educational software/systems are needed, to both improve and consolidate this data collection toll.

Acknowledgment. This work is financed by FEDER - Fundo Europeu de Desenvolvimento Regional funds through the COMPETE 2020 - Operational Programme for Competitiveness and Internationalisation (POCI), and by Portuguese funds through FCT - Fundaçãopara a Ciência e a Tecnologia within the framework of the project POCI-01-0145-FEDER-016542.

References

1. Reyes, M.R., Brackett, M.A., Rivers, S.E., White, M., Salovey, P.: Classroom emotional climate, student engagement, and academic achievement. J. Educ. Psychol. **104**(3), 700–712 (2012)
2. Martí, M.C., Mon, F.M.E.: El uso de las tabletas y su impacto en el aprendizaje. Una investigación nacional en centros de Educación Primaria. Rev. Educ. (379), 170–191 (2018) AQ2
3. Pombo, L.: Learning with an app? It's a walk in the park. Prim. Sci. **153**, 12–15 (2018) AQ3
4. Pombo, L., Marques, M.M.: The EduPARK game-like app with Augmented Reality for mobile learning in an urban park. In: 4.º Encontro sobre Jogos e Mobile Learning, pp. 393–407 (2018)
5. Crompton, H., Burke, D., Gregory, K.H.: The use of mobile learning in PK-12 education: a systematic review. Comput. Educ. **110**, 51–63 (2017)
6. Sung, Y.-T., Chang, K.-E., Liu, T.-C.: The effects of integrating mobile devices with teaching and learning on students' learning performance: a meta-analysis and research synthesis. Comput. Educ. **94**, 252–275 (2016)
7. Burden, K., Maher, D.: Mobile technologies and authentic learning in the primary school classroom. In: Burden, K., Leask, M., Younie, S. (eds.) Teaching With ICT in the Primary School, pp. 171–182. Routledge, London (2014)
8. Parsons, D.: The future of mobile learning and implications for education and training. In: Ally, M., Tsinakos, A. (eds.) Increasing Access Through Mobile Learning, pp. 217–229. Commonwealth of Learning and Athabasca University, Vancouver (2014)
9. Azuma, R.T.: The most important challenge facing augmented reality. Presence Teleoperators Virtual Environ. **25**(3), 234–238 (2016)
10. Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., MacIntyre, B.: Recent advances in augmented reality. IEEE Comput. Graph. Appl. **21**(6), 34–47 (2001)

11. Dunleavy, M., Dede, C.: Augmented reality teaching and learning. In: Spector, M., Merrill, M.D., Elen, J., Bishop, M.J. (eds.) The Handbook of Research for Educational Communications and Technology, 4th edn, pp. 735–745. Springer, New York (2014)
12. Akçayır, M., Akçayır, G.: Advantages and challenges associated with augmented reality for education: a systematic review of the literature. Educ. Res. Rev. **20**, 1–11 (2017)
13. Radu, I.: Why should my students use AR? A comparative review of the educational impacts of augmented-reality. In: 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), pp. 313–314 (2012)
14. Pombo, L., Marques, M.M.: Marker-based augmented reality application for mobile learning in an urban park - steps to make it real under the EduPARK project. In: XIX International Symposium on Computers in Education (SIIE) and VIII CIED Meeting/ III CIED International Meeting, pp. 174–178 (2017)
15. Giannakas, F., Kambourakis, G., Papasalouros, A., Gritzalis, S.: A critical review of 13 years of mobile game-based learning. Educ. Technol. Res. Dev. **66**(2), 341–384 (2017) AQ4
16. Qian, M., Clark, K.R.: Game-based learning and 21st century skills: a review of recent research. Comput. Human Behav. **63**, 50–58 (2016)
17. Ketelhut, D.J., Schifter, C.C.: Teachers and game-based learning: Improving understanding of how to increase efficacy of adoption. Comput. Educ. **56**(2), 539–546 (2011)
18. Laine, T.: Mobile educational augmented reality games: a systematic literature review and two case studies. Computers **7**(1), 19 (2018)
19. Mitchell, J.N., Sawyer, R.K.: Foundations of the learning sciences. In: Sawyer, R.K. (ed.) The Cambridge Handbook of the Learning Sciences, 2nd edn, p. 776. Cambridge University Press, New York (2014)
20. Herrington, A., Herrington, J.: What is an authentic learning environment? In: Authentic Learning Environments in Higher Education, pp. 68–77. IGI Global, Harrisburg (2008) AQ5
21. Unity Technologies: Unity (2017). https://unity3d.com/unity. Accessed 14 Feb 2017
22. PTC: PTC Releases Major Update to Vuforia – World's Leading Platform for Augmented Reality Development (2016). http://www.ptc.com/news/2016/ptc-releases-major-update-to-vuforia. Accessed 14 Feb 2017
23. Pombo, L., Marques, M.M.: The EduPARK mobile augmented reality game: learning value and usabiliy. In: 14th International Conference Mobile Learning 2018, pp. 23–30 (2018)
24. Pombo, L., Marques, M.M., Afonso, L., Dias, P., Madeira, J.: Evaluation of an augmented reality mobile gamelike application as an outdoor learning tool. Int. J. Mob. Blended Learn. AQ6
25. Martins, A.I., Rosa, A.F., Queirós, A., Silva, A., Rocha, N.P.: European portuguese validation of the system usability scale (SUS). Procedia Comput. Sci. **67**, 293–300 (2015)
26. Brooke, J.: SUS - a quick and dirty usability scale. In: Jordan, P.W., Thomas, B., Weerdmeester, B.A., McClelland, I.L. (eds.) Usability Evaluation in Industry, pp. 189–194. Taylor & Francis, London (1996)
27. Sauro, J.: MeasuringU: Measuring Usability with the System Usability Scale (SUS). MeasuringU (2011). http://measuringu.com/sus/. Accessed 10 Feb 2017
28. Bangor, A., Kortum, P., Miller, J.: Determining what individual SUS scores mean: adding an adjective rating scale. J. Usability Stud. **4**(3), 114–123 (2009)
29. Johnson, L., Becker, S.A., Estrada, V., Freeman, A.: NMC Horizon Report: 2014 K-12 Edition. The New Media Consortium, Austin (2014)