Marker-based augmented reality application for mobile learning in an urban park

Steps to make it real under the EduPARK project

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***Abstract*— The gap between the use of mobile devices inside and outside school can lead to students' disengagement with learning activities in formal education. To fill this gap, educators can take advantage of mobile devices' dissemination to give students access to educational Augmented reality (AR) systems. However, this type of exploration is relatively new, and researchers are still studying AR's advantages and challenges in education.**

In that line, the EduPARK project is developing an interactive AR mobile application to support geocaching activities in outdoor environments, thus creating situated learning opportunities. It is to be explored by students and teachers from basic to higher education, but also by the public. The project follows a design-based research methodology, with several cycles of AR application development, user testing and evaluation.

This manuscript is a work-in-progress report of the EduPARK project's options regarding the AR content and triggers, and points out some future directions.

The EduPARK's option was to use image-based AR, with marker-based tracking, to display mainly botanical content. In a first implementation experience, 74 pupils (aged 9-10 and 13-14) from two schools tested a beta version of the application and AR markers in an urban park. Some technical issues, related to the markers' recognition, were observed and registered by both pupils and monitors, leading to the revision of the markers' purposes, structure, and content. Examples of refined AR markers and content are presented and discussed in this manuscript.

Future work will include developing markerless tracking for this application in the selected urban park. Additionally, a proposal for the installation of the refined markers will be presented to the Park's management entity and the fully developed application will be freely offered to the public, promoting the autonomous exploration of this resource.

This work is useful for teachers and both educational technology developers and researchers, as an example of how to successfully develop image-based AR for outdoor settings.

Keywords*— *augmented reality; marker-based; mobile learning; science education; outdoor learning environments

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I. INTRODUCTION

In technology-driven societies, there is often a gap between the use of mobile devices inside and outside school. This gap can lead to students' disengagement with learning activities in formal education, thus, impacting negatively their academic success [1]. The introduction of emergent technologies in educational settings can promote students' motivation, enhancing their engagement for learning. Augmented reality (AR) technologies are no exception [2].

AR is typically defined as a technology that allows overlapping or aligning virtual elements (such as text, audio, still or moving images or even 3D models) with real objects of the physical environment, in real-time, producing a new experience [3], [4]. The triggering of AR content can be: 1) image-based, through image recognition, e.g. by a smartphone camera, or 2) location-based, which uses position data (from GPS or wireless network) to identify the user's location [5]. Furthermore, image-based AR can use marker-based tracking, requiring 2D labels, or markerless tracking, which uses the recognition of real environment images. Although, initially, AR required custom-made software and hardware, such as head mounted devices, nowadays, the dissemination of mobile devices allows the public to have access to AR systems [6].

In educational settings, AR has been recognized as being aligned with situated learning theory [7], [8], as it can promote authentic learning within local and contextualized environments, and constructivist learning theory [9], "as it positions the learner within a real-world physical and social context while guiding, scaffolding and facilitating participatory and metacognitive learning processes" p. 735 [4]. Even socio-constructivist approaches seem to be a frequent option to frame AR studies [10]. Moreover, AR can be another instructional approach available to educators, especially when the aim is to facilitate collaborative problem solving within a real physical environment [4]. However, only in recent years researchers have been exploring AR for educational purposes, in class and specially in outdoor environments, and are acknowledging its advantages and challenges in education [2], [11], [12].

Regarding AR advantages, a recent literature review [2] highlights that this type of technology can make boring content more enjoyable, provide immediate feedback and support autonomous learning, which might promote student motivation. Additionally, there seems to be a consensual agreement [2], [13], [14] regarding the potential of AR to increase learning performance itself. For example, AR allows 3D visualization of phenomena or concepts, which is not possible with traditional textbooks and, thus, this technology can support students' understanding of the learning content [15], [16]. Moreover, AR has been shown to be able to reduce cognitive load through the annotation of real world objects and environments and, thus, supporting understanding [17]. However, to be a relevant approach, the multimedia material should have curricular and educational relevance [11] and it needs to be well organized to prevent cognitive loads [2]. Some studies show that long-term memory retention is increased by using AR, when compared to non-AR experiences [14], [17].

On the other hand, one of the most reported challenges of AR is its usability [2]. AR technology allows a high degree of user interaction; therefore, AR experiences need to be well designed to guide the students during the process. According to the authors, if this is not taken in consideration, students may experience difficulties and learning tasks can be excessively long. In addition, technical problems, in particular with GPS for location-based AR applications, are common [2], [18], [19]. The precision errors in GPS can be problematic and cause frustration to users [10].

Considering both the advantages and the challenges of AR technologies, particularly in educational settings, the EduPARK project aims to create original, attractive and effective strategies for interdisciplinary learning in Science Education. The project team is creating an application (app) for mobile devices comprising an interactive videogame with AR and supports geocaching activities in outdoor environments, such as green urban parks. The selected environment is a park in the city of Aveiro, the "Infante D. Pedro Park" (hereinafter referred to as just "Park"), known for its rich botanic and historical patrimonies. This app's targets a variety of audiences in formal and informal education. The project is developing educational guides for specific audiences: i) 1st Cycle of Basic Education (aged form 6 to 9); ii) 2nd and 3rd Cycles of Basic Education (10 to 14); iii) Secondary and Graduate Education and iv) the tourist and general public (life-long learning). Each learning guide leads the player or group of players through a different and predefined path in the Park.

This manuscript is a work-in-progress report of the EduPARK project's options to date regarding the AR features of the app under development, particularly the markers developed as AR triggers. The next sections present and discuss: i) the project's design-based research methodology [20], which includes several cycles of AR app development, user testing and evaluation; ii) a summary of the first cycle of app development; iii) the reformulation of the AR content and respective triggers, as well as its grounding in the first cycle's results; and, finally, iv) directions of future work. This work is useful for both educational technology developers and researchers, as an example of how to successfully develop AR systems for outdoor settings for educational purposes.

METODOLOGICAL OPTIONS

The development of an AR mobile app required a design-based research approach, with several cycles [21][20]. The literature in the area of mobile AR justified the option of theoretically framing the project under situated, authentic and socio-constructivism learning theories.

A. The first development cycle of the EduPARK application

The EduPARK project developed a beta version of the mobile app, with an interactive AR quiz-based game to be played in the Park by groups of pupils in a friendly competition approach. It is designed for Android devices using Unity 5, a cross-platform game engine. The development and structure of this version is presented in previous work [22]. Due to the implementation setting – in the outdoors, without a reliable internet connection –, in addition with the literature frequently reported GPS precision errors [10], the project team decided to use image-based AR technology, with marker-based tracking. Hence, a set of provisory markers were developed and the Vuforia SDK for Unity was used for marker detection.

The beta version of the app was tested and evaluated by two classes of pupils of the First Cycle (aged 9-10) and one of the Third Cycle (aged 13-14) of the Portuguese Basic Education System, under the Open Week of Science and Technology of the University of Aveiro. This was a convenience sample, as the pupils' selection was made accordingly with their teachers' manifestation of interest of participation.

Once in the Park, the pupils were divided in several groups (of about three in each one), to test and evaluate the app. Hence, they were offered the opportunity of discuss with their peers the resources and quiz questions of the app. This option, is related with the socio-constructivist framing of the project, which posits that knowledge construction is mediated by social interaction [9].

Each group of pupils was accompanied by one adult monitor for safety reasons and also to collect observation data regarding pupils' behavior, perceptions, and critical incidents during the session. Pupils used the app to read markers and to access content and quiz questions. At the end of each session, focus groups were conducted to collect pupils' perspectives about the EduPARK game and app. They also filled in an anonymous questionnaire about students' profile and perceived usability of the app. Finally, the app's event login data were also collected.

To uncover the app's positive features and the ones needing improvement, data from monitors' observation and focus groups were submitted to content analysis [23], with categories emerging from the empirical data. Data from the questionnaires and event login were submitted to statistical descriptive analysis and a System Usability Scale (SUS) score [24], [25] was computed.

Details regarding the methodological options and results about the technical [22] and pedadogical [26] features of the EduPARK app are presented in previous works.

Fig. 1. Examples of points of interest in the park: a) an historical bandstand, b) a *Ginkgo biloba* specimen; c) the lake

Regarding the technical issues, the collected data revealed an excellent usability of the EduPARK app [22]. Additionally, students reported feeling enthusiasm and enjoyment with the use of the app. Overall, in the first cycle, results revealed an excellent usability of the beta version of the EduPARK app. In what concerns the app's inconsistencies, students pointed out difficulties in the use of some AR markers. This aspect is related with the recognition of the image use as a marker by the mobile device camera.

In what concerns pedagogical issues, several strong features of the app were identified, such as the fact it provides immediate feedback, and promotes situated and authentic learning, connected with the curricular content. Students referred that this application promotes contextualized learning, since it establishes relationships between school concepts and real life situations. The students also recognize value in this kind of mobile learning activities that move learning to contexts outside the classroom.

Other aspects highlighted by the students were their enhanced engagement and motivation to learn, as they are familiarized with this kind of technology for other purposes related to leisure activities. This led us to conclude that there are motivational advantages in linking learning with pleasant activities. Despite the use of mobile devices being perceived as an individual tool, the fact that students work in teams allowed them to discuss ideas, collaborate and negotiate in order to overcome the proposed challenges, hence, all members can contribute to the same goal [26].

Other features required refinement. For example, particularly relevant for younger pupils was the provision of adequate instructions, by attending to eventual difficulties to interpret the questions and using suitable vocabulary. Related with this is the fact they also took more time to complete the game, than the older pupils, which may be associated with the fact that they needed more time to read and comprehend written content. At last, pupils made pertinent improvement suggestions, such as including more interactive content and to animate the app's mascot to increase pupils' motivation [26].

B. *The second development cycle of the EduPARK application*

Considering the results of the fist cycle of implementation, the EduPARK team reformulated the beta version of the app. The AR triggers are, as stated before, 2D markers that are spread in the Park. In this manuscript the focus is on the revision of the AR markers location, purposes, layout/structure and content.

The markers' location is a set of points of historical interest and botanical specimens of different species, selected as representative of the Park's pedagogical richness (see examples in fig. 1). These offered opportunities for situated and authentic learning within the Park.

To allow autonomous exploration of the EduPARK app in the future and beyond the project's duration, the project team will propose to the Aveiro's Municipality the installation of permanent slabs with the AR markers in the Park, which will be an innovative feature in botanic park contexts. Thus, these slabs can have a double purpose: i) AR trigger with the use of a mobile device and ii) identification of a set of 32 botanic species without the use of such devices. Hence, any person passing by the selected botanic specimens can learn about theirs species and other relevant information, and thus, the rich biodiversity of the Park is publicized. Fig. 2 presents an example of an AR marker for a botanic specimen in the Park.

The slabs' layout/structure is always the same, similar to the one illustrated in fig. 2. However, the specific information given in each slab varies accordingly with the identified botanical specimen: the scientific and common names, its family (in biological classification), its origin and the AR marker, integrating the project's mascot.

Fig. 2. Example of a slab for *Ginkgo biloba* L. species

The AR content was originally intended to provide information to support the app player in the quiz-questions answering. Considering the general public potential interest in science education, the project team decided to additionally develop AR content associated with each slab. This content provides resources about the species (texts, photos, videos, 3D models) allowing people to access information without having to play the game. Nevertheless, if the user selects a game, the same set of markers can be used to display other AR contents, according to the learning guide of the game, to include interdisciplinary information.

At the moment, the EduPARK team is developing AR content for the 32 selected botanical species, to associate with the permanent slabs. As illustrated by fig. 3, the AR content follows a common layout/structure. More specifically, fig. 3a) shows the first screen displayed after the marker recognition by the app, with the overall structure of the AR content. It has several interactive buttons. In this particular case, fig. 3 displays some of the AR content associated with the specimen identified the slab in fig. 2.

Fig.3. Examples of AR contents associated with the marker in the *Ginkgo biloba* L. slab

Fig. 3b) and fig. 3c) show the content for two different buttons, in this case, the leaf and the species' fruit, respectively.

As mentioned before, the same AR markers used in the slabs can trigger different contents by the app. The player has access to content in AR that supports the correct answering of a specific quiz question. In the case of selection of an incorrect option, the game provides immediate feedback to the player, encouraging a reanalysis of the AR content. In the game, the player is guided to visit the AR associated with a specific slab/marker, before the question is shown.

FINAL REMARKS

It is important to highlight that this is a preliminary experience in the first stage of the EduPARK project, comprising the first cycle of a design-based research. The focus of this work is the EduPARK project's options regarding the AR contents, and respective triggers.

The data collected so far, seems to reinforce the situated, authentic and socio-constructivist nature of the learning reported by the app players. Nevertheless, this is still based on preliminary empirical data collection and further work needs to be carried out. Hence, in terms of improvement of the app's AR markers, it is planned to:

- use additional AR contents, namely animations, in order to evaluate how AR content may enrich even more the learning experience, as the beta version of the EduPARK app had limited AR capabilities;
- test with potential users the refined AR markers and app for an usability evaluation;
- assess the users' gains in terms of motivation, engagement, authentic learning, and others;
- organize more student activities with further versions of the app, to collect systematic data that might be used to better understand mobile learning in outdoor settings;
- install permanent slabs with AR markers within the Park to allow users to use the app autonomously and at any time;
- triangulate data from different origins besides students, such as teachers, monitors and external consultants.

This future work will involve overcoming some challenges, such as the usability of the EduPARK app in a wide typology of mobile devices, as the described activities were supported by mobile smartphones of the project. Another challenge is related to the adaptation of data collecting tools to the different audiences of the app, as younger users might feel some difficulties in their interpretation.

Future work will also include developing markerless tracking for this app, to increase the number of opportunities of situated and authentic learning in the selected Park. The project team will also propose to the Aveiro's Municipality to install a panel at the principal entry of the Park, to allow public free access to the stable version of the app. This, with the set of slabs, will allow the public to use the app autonomously and at any time.

The reported work is relevant not only for educators, who may take advantage of the developed available resources to promote situated and authentic learning, but also educational technology developers and researchers, as an example of how to successfully develop image-based AR for learning in outdoor settings.

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