MOBILE AUGMENTED REALITY APP WITH 3D MODELS: THE EDUCITY APP

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Abstract

The use of augmented reality technology has recently improved education and training methods. This technology has provided alternatives to the way people learn and relate to their environment. This work-in-progress study presents an approach to develop a smart learning city environment using augmented reality games to change citizens' sustainable development competencies, within the scope of the EduCITY project. The EduCITY – "Smart and Sustainable Cities with Augmented Reality mobile educational games made by and for the citizens" is a research and training project that aims to improve sustainable cities through the creation of a disruptive smart learning environment, supported by a mobile app with multimedia educational resources, such as augmented reality and 3D models. The project is focused on creating a disruptive and innovative approach to learning. The EduCITY app has developed two types of augmented reality mechanisms, namely Augmented Marker and ARBook, along with various 3D models. These models primarily consist of leaves, flowers, and fruits of specific trees found in the city. The purpose of this paper is to analyse the perceptions of university students (most of whom will become teachers in the future) about the use of augmented reality and 3D models in education. The study adopts a qualitative interpretative approach through a case study methodology. The study involved 51 undergraduate students who were selected through convenience sampling. The research was conducted as part of the 'Nature Integrated Sciences II' course at the University of Aveiro (Portugal), during the academic year 2023/24. To answer the research question "What are students' initial perceptions of augmented reality and 3D models integrated into the EduCITY app?", the research team conducted an activity with the students. The activity involved playing a game with the EduCITY app while walking around the city. At the end of the activity, students completed a questionnaire and data were analysed using descriptive analysis. The results indicate that the students perceive augmented reality and the 3D models integrated into the EduCITY app as innovative and helpful in understanding certain content. However, they also noted that the AR feature needs improvement. Future work will involve further testing of the EduCITY app to finalize it and make it available for free on the PlayStore and AppStore. After completing the app, additional user studies will be conducted to assess the functionality and user-friendliness of the EduCITY app.

Keywords: Augmented Reality, 3D models, EduCITY app, Education for Sustainable Development.

1 INTRODUCTION

The recent improvement in education and training methods has been attributed to the use of Augmented Reality (AR) technology.AR enables the integration of virtual elements, such as 3D models, with real-world objects in real time, resulting in human-computer interaction [4]. According to Azuma [4], AR applications share three common characteristics: the combination of real and virtual worlds, real-time interaction, and visualization of objects in three dimensions. This categorisation helps to understand the numerous AR applications available. The author suggests that supplementing conventional knowledge with content such as 3D objects, videos, or images can improve learning by making it more intuitive and natural. A 3D model is a virtual three-dimensional object that can be viewed from different angles. Unlike traditional 2D images, which are flat and have only length and width, 3D models add depth to the image, making it more lifelike.

According to Altinpulluk [3], the use of AR in education has a positive effect on motivation for learning. The author identified the main trends of AR in education between 2006 and 2016 and concluded that it has the potential to provide content in a three-dimensional perspective, create simultaneous and collaborative learning opportunities, make the invisible visible, and bridge the gap between formal and informal learning. Pombo and Marques [7] state that AR has the potential to transform education by providing a more contextualised learning experience. This aligns with the innovative strategy of using AR in education.

Recently, there has been a growing relationship between AR and digital games, as children and young people spend a significant amount of time playing on mobile devices. Educational researchers have started to adopt mobile AR games due to their potential in education [6]. Mobile AR games can make learning more engaging and dynamic [2]. The authors also suggest that AR technology can be a powerful tool for making connections and relating various contents in games based on the real world.

AR games enable highly interactive learning experiences, allowing players to engage in virtual scenarios that cannot be replicated in the real world. Weerasinghe and colleagues' [8] literature review indicates that numerous studies have demonstrated the benefits of using AR in educational games, including the development of collaborative, organizational, and problem-solving skills, as well as increased interest in learning content.

This study outlines an approach to developing a smart learning city environment using AR games to enhance citizens' sustainable development competencies. The study focuses on EduCITY (https://educity.web.ua.pt/), a work-in-progress project. The EduCITY project aims to improve sustainable cities through the creation of a disruptive smart learning environment, supported by a mobile app with multimedia educational resources. The project's goal is to create 'Smart and Sustainable Cities with AR mobile educational games made by and for the citizens.' The app includes two mechanisms of AR: Augmented Marker and ARBook, which feature 3D models. The ARBook 3D models illustrate the flowers, fruits, and leaves of various tree species found in Aveiro city. These models provide an interactive and visually engaging method for users to explore and understand the intricate details of natural elements. Creating accurate and detailed 3D models of flowers, fruits, and leaves can deepen users' appreciation for the complexity and beauty of the natural world. This hands-on approach fosters a greater awareness of nature. Interactive learning is facilitated by 3D models as they enable users to manipulate and explore objects in a virtual space.

This hands-on approach enhances learning by allowing users to interact with 3D models. Users can rotate and zoom in to examine details. To create a 3D model, specialized software is necessary. The software defines the shape, colour, and sometimes even the behaviour of the object in a virtual space. Once created, the 3D model can be manipulated and viewed from various perspectives, providing a more immersive and interactive experience. To create the 3D models of the leaves, each leaf was photographed from both sides without zooming and on a white background. The model was then assembled using Blender. In addition, the 3D models of the flowers and fruits were created using the Polycam Pro app, a 3D capture app. The process of developing the 3D models went through the design-based research methodology, with successive cycles of improving the prototype until reaching the final object. AR and 3D models were integrated into a game and tested with second-year Basic Education students at the University of Aveiro.

This paper aims to demonstrate how AR content and 3D models can enhance learning and motivate students.

The research methodology, including the case study and data collection and analysis methods, is outlined. The results are then presented and discussed, leading to the key conclusions as the primary contribution of this study.

2 METHODOLOGY

This paper adopts a qualitative interpretive approach [1] through a case study methodology, which is recognised in the literature as a powerful tool for investigating and understanding complex issues in real-world settings [9].

The study focuses on analysing the perceptions of university students, who are mostly future teachers, regarding the use of AR and 3D models in education. The research question that guided this work is: 'What are students' initial perceptions of Augmented Reality and 3D models integrated into the EduCITY app?' The main objective is to analyse the opinions of undergraduate students in Basic Education who have used the EduCITY app. Specifically, we will examine their views on: (i) the usability of Augmented Reality and 3D models; (ii) the educational usefulness of AR; (iii) the ease of playing an AR game; and (iv) their satisfaction with using AR and 3D models.

To accomplish this goal, we first present the AR content and 3D models integrated into the EduCITY app. Then, we describe the case study for contextualisation, followed by the data collection and analysis approach.

2.1 Augmented reality content and 3D models integrated into the EduCITY app

The EduCITY app offers two mechanisms for developing AR content: Augmented Marker and ARBook. Augmented Marker is a template that enables users to create interactive buttons in AR. These buttons are placed on specific pixels of an image and provide access to digital information (see Figure 1). The purpose is to enable users to associate blocks of textual information with different parts of the image. The Augmented Marker can feature up to nine interactive buttons, each providing distinct information related to a specific part of the highlighted image. It offers various features, such as dual language support and a flexible template that enables users to insert any type of information into any image and position. Additionally, it provides the option to lock the AR information displayed on the mobile device screen, enabling the user to move away from the marker without losing the relevant information.

Figure 1. Example of an Augmented Marker

The ARBook is a template for a dynamic AR menu that can incorporate 3D content and provide information that complements reality. It provides detailed information on tree species, including characteristics such as plant, leaf, flower, fruit, origin, ecology, and curiosities. ARBook enriches the user experience by triggering AR information whenever the camera locates a marker (plaques installed with pre-defined markers in the city of Aveiro). The ARBooks integrate 3D models (see Figure 2). Selecting the 'Plant' button displays information about the plant's height and trunk. The 'Leaf' button provides a description of the leaf's morphology, which may include a photograph or 3D model. The 'Flower' and 'Fruit' buttons function similarly. On the right-hand side of the board, the 'Origin' button indicates whether the plant species is native or exotic, supported by a map highlighting its distribution. The 'Ecology' button displays the plant's habitat and the months in which it flowers or bears fruit, accompanied by illustrative photographs. The 'Curiosities' button provides a range of information, such as the definition of scientific and common names, as well as other relevant facts, including its medicinal applications.

Figure 2. Example of an ARBook

The Augmented Marker and ARBook were developed to enable their creation by the EduCITY team or other users, such as teachers or students, without programming skills. This ensures greater flexibility and project sustainability beyond the funding period.

However, the scanning method for the 3D models integrated into the ARBook was not consistent across all objects. To produce the 3D models of the leaves, each leaf was photographed from both sides without zooming and on a white base. The Blender program was used to assemble the model. Furthermore, the Polycam - Lidar & 3D Scanner app (version 3.1.30) was used to create the 3D models of the flowers and fruits (Figure 3).

Figure 3. Examples of 3D capture using the Polycam Pro app

The scanning method used for the 3D models was inconsistent across all objects. The Polycam app is available in both a free version, which only allows the export of the mesh and/or point cloud, and a paid version (with a monthly or annual fee) with more advanced functions, mainly aimed at metric documentation and exporting in different formats. This app enables the user to scan objects by selecting between the LiDAR, ROOM, and PHOTO options. For EduCITY, all objects were scanned using the 'photo' mode because of their small size.

The flowers and fruit 3D models were placed at the centre of a rotating wooden base. This enabled the mobile phone to capture around 60 photos of each object, maintaining a consistent distance of approximately 20 centimetres between the object and the mobile phone. The app then processes these images to generate a 3D model. To obtain accurate geometry reconstruction, it is necessary to photograph the object from various angles. To accomplish this, we employed a rotating base.

This paper examines the perceptions of university students regarding the use of AR and 3D models in education. The case study is outlined below.

2.2 Case study

This study involves 51 second-year Basic Education students at the University of Aveiro who undertook the “Nature Integrated Sciences II' curriculum, with a specific focus on the subject of 'Biodiversity and Conservation”. It is important to note that the participants in this study were selected using a convenience sampling method, which means that they were included based on their convenient availability within the context of the 'Nature Integrated Sciences II' curricular unit.

To ensure a comprehensive general science education, this curricular unit incorporates features of the EduCITY app, such as mobile learning, game-based learning, and augmented reality. The aim is to combine theoretical concepts with practical experiences and technology, enhancing the overall learning experience for students.

An activity was organized by the research team for the students to gather data. While walking from the University of Aveiro to the city centre, the students played a game using the EduCITY app. The game introduced them to various types of AR and 3D models while they answered a series of questions. The game integrates seven points of interest, each with three questions, and incorporates educational multimedia resources, AR content, and 3D models that cover interdisciplinary issues related to sustainability.

2.3 Data collection and analysis

To address the research question "What are students' initial perceptions of Augmented Reality and 3D models integrated into the EduCITY app?", we collected students' opinions on the AR experience and the EduCITY app. The students played a game in groups for approximately one hour, after which they

completed an individual online questionnaire. The questionnaire consisted mainly of closed questions with multiple choice, item selection and a five-point Likert scale. However, it also included open questions. The questionnaire is divided into three sections: Section A pertains to the student profile regarding the use of mobile devices for learning; Section B pertains to the mobile game-based activity with AR application as a methodological strategy for learning; and Section C pertains to the satisfaction of exploring the application. This paper analyses four questions from section C regarding AR content.

One of the aims of the questionnaire was to collect information on students' opinions about the usability and pedagogical usefulness of the EduCITY app, as well as the ease and satisfaction of using the app with AR. The collected data does not contain any personal information, and individual participants cannot be identified.

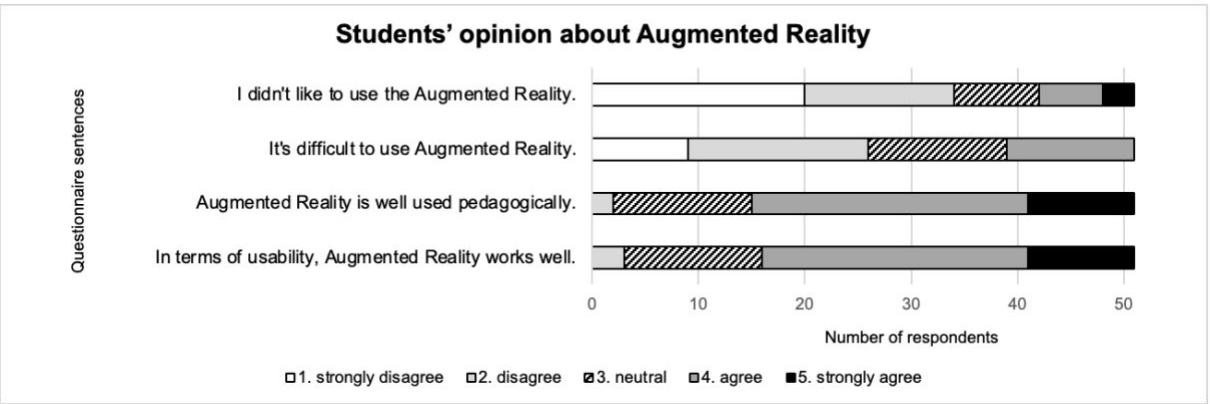
3 RESULTS AND DISCUSSION

This section provides a concise and accurate description of the experimental results, their interpretation, and the experimental conclusions that can be drawn.

The results of the case study on the AR content in the EduCITY app and its educational value, as perceived by 51 second-year basic education students, are presented.

Graph 1 displays the students' opinions about the value of the AR content in the EduCITY app. Approximately 36 students rated it with levels 4 and 5 (agree and strongly agree), suggesting that they believe the AR content in the app has a significant impact on learning outcomes. The responses of the students indicate that they placed significant emphasis on the pedagogical value of the EduCITY app. This positive perception of the educational potential of AR technology is noteworthy. In terms of the app's usability, the majority of students found that the AR function worked well. Specifically, 25 students agreed and 10 strongly agreed, while 13 students were neutral. When asked about the ease of using the EduCITY app, 26 students disagreed or strongly disagreed that the AR function was difficult to use, 13 students were neutral, and 12 students agreed. None of the students strongly agreed. The results suggest that students believe that improvements are necessary in AR to enhance its usability. These findings were anticipated as the application was still in the testing and improvement phase.

Finally, in terms of satisfaction with exploring the EduCITY app, students responded to the question "I didn't like using Augmented Reality", which was deliberately written in the negative to assess students' attention. In response to this question, levels 1 and 2 are expressed by 20 and 14 students respectively. However, 8 students gave a neutral answer, 6 students agreed and 3 students strongly agreed. Therefore, these students recognise that the AR content in the EduCITY app is relevant and exciting, providing a more motivating learning experience.



Graph 1. Students' opinion about Augmented Reality content at the EduCITY app

It is important to note that during this test activity, the students played a game on an Android application pack (apk) that was still in development. This caused technical issues during the game experience. Therefore, the experience of using the app (e.g. fast/slow, unpredictable/predictable) may differ from one mobile device to another, resulting in different impressions for users from different groups.

This paper addresses an open question in the feedback questionnaire for the EduCITY app [5]. The results of the students' feedback on improvements are summarised in Table 1. The main themes of the responses were analysed without any sampling, meaning that all responses were considered. The

coding scheme was developed based on the data themes. Three students did not provide any improvement feedback, while the remaining respondents provided a total of 48 suggestions, relating to:

a) Efficiency (14 comments), where the main suggestion was to improve the usability of the AR;

b) Perspicuity (1 comment), regarding the improvement of the clarity of some texts;

c) Attractiveness (33 comments), most of them highlighting the high quality and innovation of the EduCITY application.

Table 1. Students' feedback about the EduCITY app

Category	Sub-category	Frequency	Examples
Efficiency	Address app bugs	6	*"This is a recent game, so it still has a few bugs, but it's interesting in a way because it's different from the usual" A44*
	Address AR bugs	8	*"I think there are some aspects to improve. The AR wasn't being used at all the points of interest (…)" A20*
Perspicuity	Reformulate texts/information for improved clarity	1	*"Some feedback texts could have been worded better, especially after questions with more than one wrong answer - when you read the text you can't tell which ones were wrong or right (…)" A4*
Attractiveness	Pedagogical usefulness	14	*"A very engaging learning method for children" A22*
	High-quality and innovative	16	*"It was very interesting and a very pleasant way to discover the city of Aveiro, (…)" A36*
	AR useful for learning	3	*"The app is interactive. I like the fact that the mascot (the flamingo) interacts and gives feedback, and that it presents different forms of technology and content. Even though augmented reality isn't 100% there yet, it's innovative and I think it has a lot of potential." A34*
No comment	-	3	

Based on the results, the students highlighted the app's attractiveness, quality, and innovation (16 students), as well as its pedagogical usefulness (14 students) and facilitation of learning through AR (3 students).

The students identified two areas for improvement: efficiency and perspicuity. Specifically, the students suggested that the app and AR require some improvements in terms of efficiency (6 students) and that the app needs to be more perspicuous (8 students). Additionally, while the app is interesting and dynamic, it could benefit from improvements to the ease of visualising the AR as it has been observed to crash at times. One student suggested that some feedback texts could be better formulated, particularly after questions with more than one incorrect answer, to improve clarity.

During the activity, the students showed enthusiasm for the app. They demonstrated curiosity by asking several questions and ultimately expressed their admiration for the app and its use of augmented reality.

4 CONCLUSIONS

This work-in-progress study presents an approach to develop a smart learning city environment, called EduCITY, using AR games to enhance citizens' sustainable development competencies. The study focuses on analysing the perceptions of university students. This was the first data collection of the project to analyse AR and 3D models. In this activity, students explored the different types of AR and 3D models while answering the proposed questions. At the end of the activity, the participating students completed an individual online questionnaire. It is important to note that the application is still under development, so the use of evaluation tools during this phase is relevant.

According to the participating students, the overall perception of the EduCITY app and AR content is positive. While the students acknowledge the high potential of AR, they suggest that it could be improved. In the open response section of the questionnaire, students mentioned that AR is very innovative and interesting, and facilitates learning, but still requires some adjustments and improvements.

Overall, the integration of AR and 3D modelling into sustainability and nature education provides a dynamic and engaging way for students to explore and understand complex concepts. This approach encourages creativity and critical thinking. It is important to note that any subjective evaluations have been excluded from this analysis.

Future work involves conducting further testing of the EduCITY app to finalise it and make it available for free on the PlayStore and AppStore. Once the app is finalised, additional user studies will be conducted to evaluate the features and usability of the EduCITY app.

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REFERENCES

[1] J. Amado, *Manual de investigação qualitativa em educação*. Coimbra, Portugal: Imprensa da Universidade de Coimbra, 2017.

[2] M. Akçayı & G. Akçayır, "Advantages and challenges associated with augmented reality for education: A systematic review of the literature," *Educational Research Review,* vol. 20, pp. 1-11, 2017. Retrieved from https://doi.org/10.1016/j.edurev.2016.11.002

[3] H. Altinpulluk, "Determining the trends of using augmented reality in education between 2006-2016," *Education and Information Technologies,* vol. 24, no. 2, pp. 1089 –1114, 2019. Retrieved from https://doi.org/10.1007/s10639-018-9806-3

[4] R. Azuma, "A survey of augmented reality," *Teleoperators and Virtual Environments,* vol. 6, pp. 73–272, 1997. Retrieved from https://doi.org/10.1561/1100000049

[5] J. Forman & L. Damschroder, *Qualitative Content Analysis.* Oxford, UK: Empirical Methods for Bioethics: A Primer. 2008

[6] T. H. Laine, "Mobile educational augmented reality games: A systematic literature review and two case studies," *Computers,* vol. 7, no. 1, 2018. Retrieved from https://doi.org/10.3390/computers7010019

[7] L. Pombo & M. M. Marques, "An app that changes mentalities about mobile learning—the EduPARK augmented reality activity," *Computers,* vol. 8, no. 2, 2019. Retrieved from https://doi.org/10.3390/computers8020037

[8] M. Weerasinghe, A. Quigley, J. Ducasse, K. C. Puciharand and M. Kljun, "Chapter 1 – Educational Augmented Reality Games," in *Augmented Reality Games II: The gamification of education, medicine and art* (V. Geroimenko, ed.), pp. 3 – 32, Springer, 2019. Retrieved from: https://doi.org/10.1007/978-3-030-15620-6_1

[9] R. K. Yin, *Case Study Research: Design and Methods.* Sage, CA, USA: Thousand Oaks, 2014.