# MOBILE AUGMENTED REALITY GAMES FOR AUTHENTIC SCIENCE LEARNING: PERSPECTIVES OF STUDENTS (FUTURE TEACHERS) ON THE EDUCITY ACTIVITY

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## Abstract

The use of mobile devices in formal learning situations is a controversial issue as it is widely associated with leisure time and distraction, although it can be used to engage, enhance, complement, and even redefine learning strategies. In a technology-driven society, teachers can take advantage of the ubiquity of technological devices to innovate their pedagogical practices to promote student engagement for deeper and authentic learning. The recent proliferation of applications makes augmented reality technology accessible to support learning anytime anywhere, even in outdoor environments, such as urban parks or cities. This paper focuses on an innovative experience with university students, most of whom will become teachers in the future. It describes the new pedagogical approach involving the use of mobile augmented reality games, where students play a dual role: players and game designers. It follows a qualitative interpretive case study methodology, using a convenience sample of 51 undergraduate students. The research objective is to analyse students' opinions about this innovative experience and the EduCITY app, so a questionnaire was used and data were analysed using descriptive analysis. The study finds that EduCITY is an activity that helps students learn more about the heritage and culture of a particular region in an innovative and technological way. The students reported finding the activity more engaging during the field trip than if it had been conducted in the classroom. This was due to the opportunity to experience the challenges in a real-world context. Additionally, the combination of outdoor environments and new technologies, such as augmented reality, can exponentially enhance the educational effect and result in increased student engagement in science learning.

Keywords: Authentic learning, Games and mobile learning, Education for sustainability, Innovation in Higher Education.

## 1 INTRODUCTION

There are several challenges facing Higher Education institutions. One of the major challenges in Higher Education is the growing trend of the influence of technology in students' lives and the constant need for professors to follow this technological evolution in order to keep up to date and offer challenging and innovative proposals. Mobile devices, especially smartphones, have become an integral part of our daily lives, as they can be used to keep in touch with family and friends, to share daily experiences with others, but also to learn in formal learning environments, and to connect with informal or situated learning with the classroom, promoting authentic learning [1]. Rather than focusing on strategies to prevent students from being distracted by their mobile devices in formal learning situations, it is important to experiment and analyse the exploration of mobile devices to engage, enhance, augment, and even redefine strategies to help students to learn [2]. In a technology-driven society, professors and teachers can take advantage of the ubiquity of technological devices to innovate their teaching practices to promote student engagement for deeper and authentic learning [3]. Like mobile phones, games are also associated with leisure time. Video games, in particular, can be highly motivating for players, who can devote considerable time and resources to them [4]. In Education, games have long been studied to promote learning, and the literature has shown that when games are carefully designed to scaffold appropriate learning objectives, they can also increase students' motivation and engagement in learning [5], [6].

Therefore, the use of innovative methods outside the routine, such as field trips, visits to museums or science centres, or even outdoor games, is essential. Introducing contexts other than the classroom into the learning process could improve motivation, but can also play an essential role in making connections between what students observe in their environment and what they have learned in class, in a perspective of education for sustainability.

When games are explored in outdoor environments and combined with new technologies, such as augmented reality (AR), the educational effect can be exponential [7], leading to changes in citizens' attitudes towards conservation, for example. The recent proliferation of apps makes AR technology accessible to support learning anytime and anywhere, even in outdoor environments, such as urban parks [8] or the city itself [9].

Today, environmental issues are of concern to all countries, especially for developing countries, and education for sustainability is urgent. However, improving students' learning and engagement in environmental education remains a challenge. Researchers have highlighted the potential of digital games to enhance students' learning motivation [10]. In addition, according to the 2030 Agenda, sustainable cities and communities is a relevant societal goal that guides us towards efficient urban planning and management to address the challenges posed by intense urbanisation, such as traffic congestion, waste management, and pollution, all of which are topics to be studied in scientific disciplines. To address these challenges, students must be empowered both to reflect on their actions and to act sustainably in complex situations [11]. Therefore, promoting opportunities to develop key competencies in sustainability is crucial [10].

The EduCITY project (https://educity.web.ua.pt/) is based on an action-oriented transformative pedagogy, which is essential for the development of key competences for sustainable development. The project uses smart technology, such as mobile AR games, to create challenging pathways that take education out of the classroom. The integration of a mobile game-based app, as a practical technological solution, along with this new knowledge, has the potential to challenge conventional thinking about student learning [12]. This strategy is currently being implemented in the 'Nature Integrated Sciences II' course at the University of Aveiro (Portugal). This curricular unit adopts the Science-Technology-Society-Environment approach, which situates science teaching in real-life contexts, more or less close to the students. Students, most of whom will be teachers in the future, experience a mobile game-based learning approach using the EduCITY app [13]. They play a dual role: as game players, simulating basic education students, and as game creators, simulating teachers. A case study was conducted on the topic "Biodiversity and Conservation" within the curriculum unit. The research aimed to understand students' opinions on the educational value of the app and their experience with mobile learning in natural science. As mobile learning studies often focus on teachers' perspectives [14], this study provides valuable insights into students' experiences.

The aim of this research is to describe the mobile learning experiences of science students at university and to determine how different pedagogical dimensions affect their perceived learning. It also aims to provide valuable insights for educators who wish to design authentic mobile learning environments, replacing outdated pedagogies with new ones and introducing new learning activities that were previously difficult, or impossible to implement, without mobile devices.

The paper is structured as follows: firstly, the research methodology is presented, including the case study and the data collection and analysis. Secondly, the results are presented and discussed. Finally, some conclusions are presented as the main contribution of this study.

## 2 METHODOLOGY

This paper employs a qualitative interpretive methodology [15] for a case study [16] to answer the research question: 'What is the relevance of a mobile game-based activity with AR app, for outdoor exploration, as a pedagogical strategy in a science discipline?' The aim of this study is to analyse the opinions of undergraduate students of Basic Education who have experienced the EduCITY app, regarding: i) the effectiveness of the mobile game-based activity with AR app as a methodological strategy for learning; ii) the pedagogical usefulness of the app; iii) their satisfaction with exploring the app; and iv) their overall impression of the app. To accomplish this goal, the EduCITY app is first presented, followed by the description of the case study for contextualisation, followed by the data collection and analysis approach.

## 2.1 EduCITY app

The project "EduCITY - Smart and sustainable cities with mobile educational games in Augmented Reality created by and for Citizens" (https://educity.web.ua. pt/) is a project at the University of Aveiro that combines research, training, and development, and its feasibility is made possible by a multidisciplinary team, from areas, such as Education and Training; Environment, Sustainability and Sustainable Development; and Multimedia and Computer Technology.

The development of the EduCITY project is based on five main areas of orientation and innovation, namely: i) turning the city into an experimental living laboratory; ii) exploiting the potential of smart technology; iii) using mobile devices such as smartphones and low-cost, easy-to-use environmental sensors; iv) enabling active participation and community involvement; promoting knowledge sharing; and v) enabling the project to be explored in other urban areas, promoting its scalability.

The EduCITY aims to promote the development of sustainable cities through the implementation of an innovative and interactive learning environment. The challenges are contextualised in concrete and real situations. The mobile app integrates interdisciplinary challenges enriched with augmented reality educational resources (Figure 1), including simulations based on data from environmental sensors, 3D models, and informative content, among others.
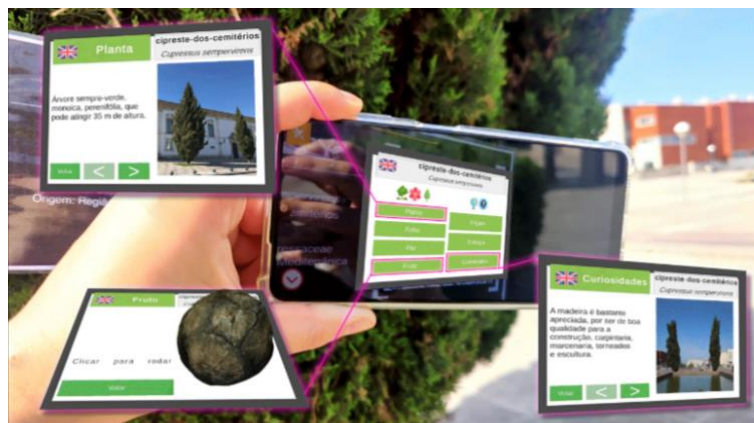


*Figure 1. Educational resource with Augmented Reality*

The games are collaboratively developed by the school community, academics, and the general public. They include interdisciplinary and playful challenges intended for exploration by all citizens as they interact in the city. In this study, the university students were invited to participate in creating a game.

The EduCITY project adopts an innovative pedagogical approach that uses everyday technology, such as mobile devices, to promote practical, in-context learning, in which Augmented Reality games play the role of a means of raising awareness of sustainable development in the city, acting as a dynamic laboratory for experimentation [17]. This paradigm is based on the concept of citizens as 'active scientists' and agents promoting sustainable change, in line with the principles and dynamics of citizen science. Based on these principles, it was necessary to provide access to the creation of resources and games that would promote the same changes and enrich the whole project. To this end, a web platform has been developed, open to all but moderated by the team.

The EduCITY app (shown in Figure 2) has undergone several iterative development cycles. It is characterised by a careful balance between usability and the rigor of the information presented. The dynamics of all games follow a consistent structure, divided into categories of spatial orientation, question introduction, questions themselves, and answers with feedback for both correct and incorrect responses.
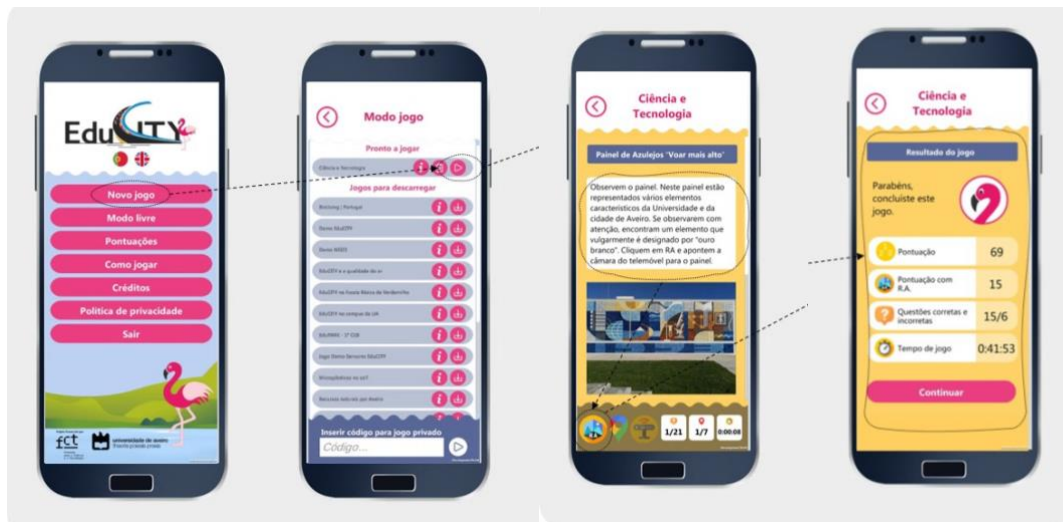
*Figure 2. The EduCITY app with location-based mobile games comprising AR and multimedia contents.*

All these stages must be accompanied by multimedia resources. The process of answering questions should be repeated as many times as necessary, and the game must conclude with a final message. A screen displaying some of the game's statistics should follow (see Figure 2).

One of the innovative aspects of the EduCITY strategy is to take learning beyond the traditional classroom environment to a specific natural space in a city that visitors can explore physically while making connections to curricular content.

## 2.2   Case study

This study analysed a convenience sample of 51 second-year undergraduate students from the University of Aveiro who were enrolled in the curricular unit 'Nature Integrated Sciences II' with a focus on 'Biodiversity and Conservation'. This is therefore a convenience sample.

This curriculum unit promotes a holistic approach to science education, based on the Science-Technology-Society-Environment (CTSA) movement. The approach places science teaching in real-life contexts, which can be more or less closely related to the students. This approach leads to the emergence of links between science and technology, with implications for and on society. The curriculum also discusses ethical aspects of science, principles and values of scientific knowledge, the relationship between science and culture, the nature of science, scientific controversies, as well as the social implications of scientific and technological development.

The curriculum unit covers fundamental topics in general science education. The module "Biodiversity and Conservation" includes a preparatory lesson that provides theoretical context for mobile learning, game-based learning and augmented reality. It also introduces the EduCITY project, the app's features, the field trip preparation, and the assessment strategy. The field trip consisted of a walk from the University of Aveiro to the city centre. The game comprises seven points of interest, each with three questions and various educational multimedia resources. The questions cover interdisciplinary issues related to sustainability. The students played the game in groups for approximately an hour. The evaluation strategy involves group elaboration and presentation of questions related to a specific point of interest chosen by the students. The questions should be integrated with original educational resources based on the essential learning of the second cycle of basic education, such as biodiversity, pollution and the general characteristics of animals and plants. The aim is to support learning through creative use of resources, such as AR or multimedia content. The result is a new game that will be published in the EduCITY app and will be freely available to all.

## 2.3   Data collection and analysis

The aim of this paper is to answer the research question: 'What is the relevance of a mobile game-based activity with an AR app for outdoor exploration as a pedagogical strategy in a science discipline?' To achieve this, the study collected students' opinions on the innovative experience and the EduCITY app through an anonymous questionnaire after the activity.

This questionnaire aimed to collect students' opinions of the outdoor activity proposed in 'Nature Integrated Sciences II' and the EduCITY app they explored. The data was collected anonymously and individually to evaluate and enhance the activity and application. The questionnaire comprises mainly closed questions with multiple-choice, item selection, and a five-point Likert scale, along with open questions. The article is divided into three sections. Section A discusses the student profile in relation to the use of mobile devices for learning. Section B focuses on a mobile game-based activity that uses AR application as a methodological strategy for learning. Finally, section C explores user satisfaction with the mobile app.

## 3 RESULTS

This section provides a brief description of the participants and contextual aspects of the EduCITY activity. Subsequently, the students' perspective on the EduCITY app is presented, focusing on its pedagogical usefulness and their satisfaction with its use.

### 3.1 Characterisation of the participating students

Fifty-one students participated in this study and completed the questionnaire. Of these, 49 were female and 2 were male. The age range of the participants was between 18 and 48, with 19 being the most common age. The majority of students had studied 'Languages and Humanities' (23 students) or 'Science and Technology' (13 students) as part of their secondary education.

Graph 1 displays the frequency with which students reported using smartphones to support their learning. Out of the 44 students surveyed, 21 reported using them frequently, while 22 reported using them daily. Only one student reported never using a smartphone for learning, and one student reported using it only a few times.
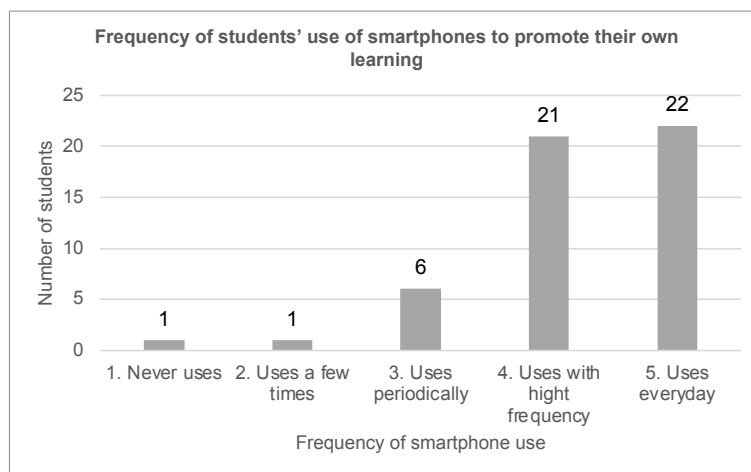


*Graph 1. Frequency of students' use of smartphones to promote their own learning*

When asked about the context in which they use smartphones to support their own learning, most students selected multiple options. The main context for learning with mobile phones was 'at the university' by 50 students. Additionally, 48 students reported using their smartphones to study at home. Some students also mentioned learning with their smartphones while watching documentaries (14 students), on the train (12 students), and while travelling (1 student).
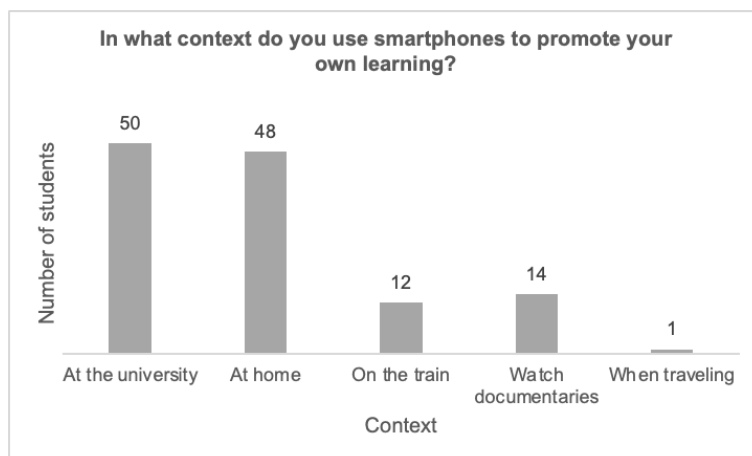
**Graph 2. Frequency of students' context of smartphones use**

In the open-ended questionnaire, students reported that mobile phone learning has several advantages, including ease, speed, practicality, accessibility, and dynamism. However, they also noted some disadvantages, such as exposure to fake news, frequent distractions, low battery life, and internet failures.

## 3.2 Evaluating the activity, as a smart learning city environment

Regarding the evaluation of the EduCITY activity by students, they were asked to rank it on a scale of 1-5 (where 1 represents strong disagreement and 5 represents strong agreement). Additionally, they were asked to provide their opinion of the activity in an open-ended question.

The results indicate that graduating students believe that the activity was appropriately timed, as no students selected options 1 or 2 (Graph 1). Furthermore, the students found the methodology to be adequate. One student strongly disagreed that the methodology was adequate. In terms of the resources used, 34 students found them interesting, 8 students answered neutrally, and 9 students said they were not interesting. With regards to the sentence 'The proposed tasks were too difficult', 13 students strongly disagreed, 20 students disagreed, 16 students had a neutral answer, and 2 students agreed.

The graph shows that no student answered level 1, and the majority answered 4 and 5 (41 students). The students were satisfied with their participation in the EduCITY activity. Additionally, the future teachers feel prepared to use this type of activity with their own students in the future, as shown in the graph with option 4 (18 students) and 5 (25 students) selected by the students. Graph 1 shows that the students were satisfied with the activity and would recommend it to their peers (41 students).

**Students' opinion of the activity**
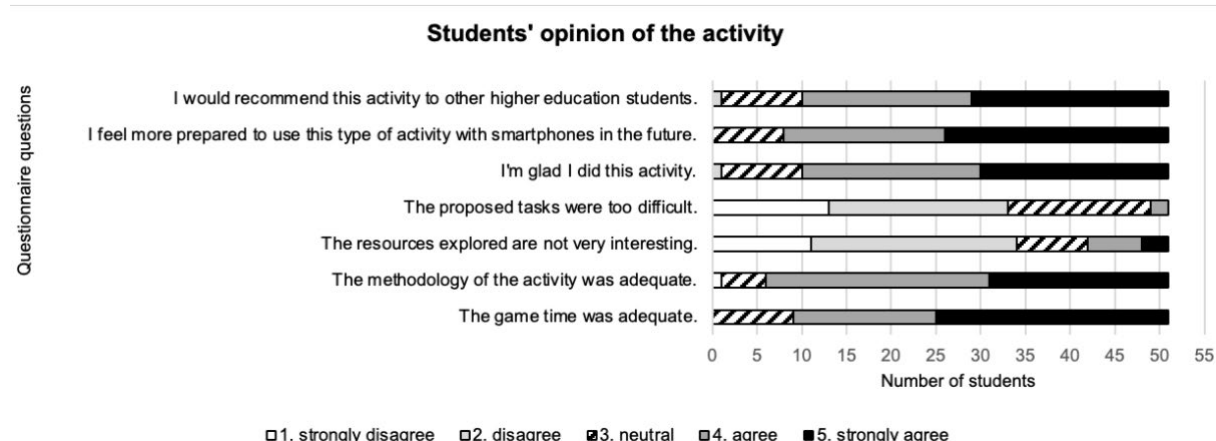
**Graph 3. Students' opinion of the EduCITY activity**

This section included an open-ended question for students to provide feedback on the EduCITY activity. The feedback was analysed using inductive categorical content analysis [18]. The unit of analysis was the main themes of the answers, and all answers were analysed as no sampling was conducted. The coding scheme was developed based on the data themes: learning value, intrinsic motivation,

engagement, authentic learning, lifelong learning, and app issues. Table 1 summarises the students' opinions, with a total of 51 feedback about the EduCITY activity.

*Table 1. Students' feedback about the EduCITY app*

| Category | Sub-category | Frequency | | Examples |
|---|---|---|---|---|
| **Learning value** (the ability of the EduCITY activity to promote learning) | **Content** (ability of the activity to support substantive knowledge learning. E.g., learning some content). | 5 | 7 | "A different way of learning content." A12 |
| | **Skills** (ability of the activity to promote skills development. E.g., teamwork). | 2 | | "It was a pleasant group activity that helped with socialising and acquiring knowledge." A31 |
| **Intrinsic motivation** (the ability of the EduCITY activity to promote participation for its own sake. E.g., for the pleasure and satisfaction derived from it) | **Enjoyment** (ability of the activity to be enjoyable/fun/ pleasant) | 11 | 24 | "EduCITY is an activity that helps us, in a more up-to-date and technological way, to learn more about the heritage and culture of a particular region. I felt that the activity aroused more interest during the field trip than if it had been carried out in the classroom, as we had the opportunity to be in contact with the challenges and the city itself." A1 |
| | **Interest** (the ability of the activity to be interesting for itself) | 13 | | "I found it interesting to go out into the city to do the tasks and find out more about the points of interest we passed." A2 |
| **Engagement** (the ability of the EduCITY activity to promote the participants' active involvement) | - | 9 | | "It was very interesting, interactive, and fun. I really enjoyed it and I want to do more activities like this." A33 |
| **Authentic learning** (ability of the EduCITY activity to promote learning in a real-world context, in ways that are meaningful to the participant) | - | 2 | | "An activity that should be more widely implemented in education, since the new generation is very connected to smartphones (...)". A32 |
| **Lifelong learning** (the ability of the EduCITY activity to support ongoing and voluntary learning throughout participants' lives) | - | 1 | | "Very interesting. I learned content that I'll never forget." A11 |
| **App issues** | - | 5 | | "It was interesting, but as the app was still in its initial release phase, my group was constantly stopping to give feedback on bugs. If we had been at a later stage, perhaps the activity would have been better utilised." A4 |
| No comment | - | 3 | | |

The most commonly cited impact of the EduCITY activity was 'Intrinsic motivation', with a total of 24 assertions. The data analysis revealed that the students generally found the activity interesting (13 students) and enjoyable (11 students). Additionally, the results suggest that graduating students perceive the EduCITY activity as highly engaging and conducive to learning (9 students).

The category that received the third highest number of citations was 'Learning value', with seven mentions across two dimensions of analysis. Students emphasized the importance of the learning of 'content', which was mentioned five times. Additionally, two students noted that the activity helped them develop group work skills. The students also highlighted that the EduCITY activity facilitated authentic learning (2 students) and lifelong learning (1 student).

It is worth noting that the students identified a negative aspect of the activity, namely the bugs and problems with the app (mentioned by 5 students). Although the students acknowledged that the app was still in development, they considered the bugs to be a significant drawback.

## 3.3 Evaluating the eduCITY app

Graph 4 presents students' opinions on the pedagogical usefulness of the EduCITY app. Overall, the graph indicates that students consider the EduCITY app to be a valuable educational tool. The students find the app easy to use and believe it would be useful in future lessons with their students, as no student indicated disagreement with these two statements. Additionally, the students noted that the app is user-friendly and achieves its proposed objectives. However, some students reported encountering bugs with the app during the activity. Regarding the statement 'The app is useful for learning', 4 students responded neutrally, 24 agreed, and 23 strongly agreed. These results suggest that, despite being in the development phase, the EduCITY app is perceived as a valuable tool for learning by the students.

The results suggest that the graduating students perceive this activity as having a significant impact on the participants' learning and contributing to a positive perception of the educational potential of mobile learning strategies.
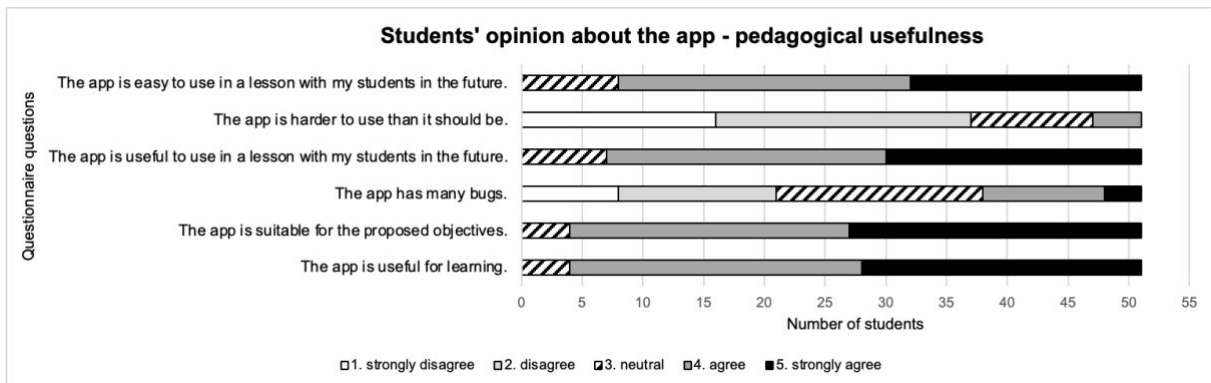


*Graph 4. Students' opinion about the pedagogical usefulness of the EduCITY app*

At the end of the questionnaire, students were asked to rate their satisfaction with the EduCITY app. According to Graph 5, 44 out of the total number of students answered positively to the statement 'the videos and images are interesting', while only 7 answered 'neutral'. In response to the question 'I felt confident using the app', 13 students strongly agreed, 22 students agreed, 14 were neutral, and 2 students disagreed. Regarding satisfaction with the app, most students responded with 'agree' or 'strongly agree', with 27 and 15 students respectively. It is worth noting that 8 students were neutral, and only 1 student disagreed. According to the students' responses, 16 of them strongly agreed and 27 agreed that they would recommend the EduCITY app to a friend or family member. Additionally, 36 students expressed their desire to use the app more frequently. Furthermore, 21 students strongly agreed and 23 agreed that they found using the app enjoyable, indicating that the activity is very pleasant.
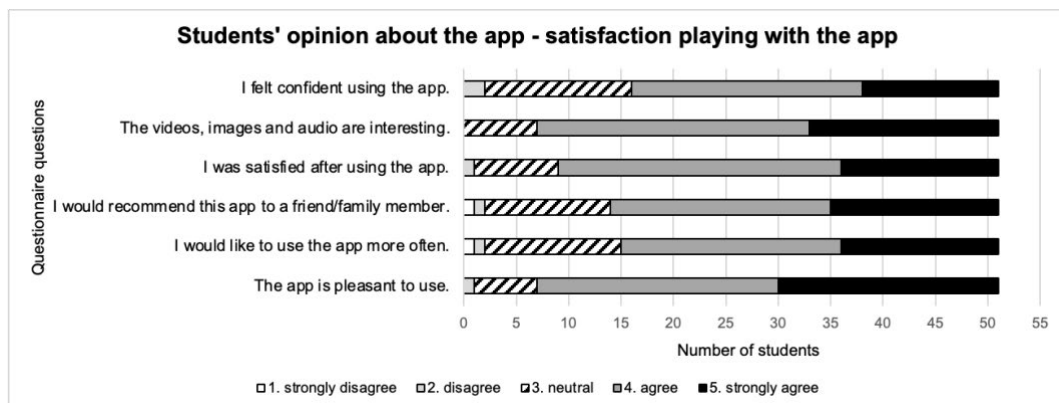


*Graph 5. Students' opinion about the satisfaction of playing with the EduCITY app*

In conclusion, the survey results show that students have given overwhelmingly positive feedback about the EduCITY app. This is evidenced by high satisfaction levels with both the content and usability of the app. The majority of students expressed a strong willingness to recommend the app, while a substantial

number indicated a desire for more frequent use. This underscores the effectiveness of the app as an enjoyable and valuable educational tool.

## 4 CONCLUSIONS

Based on the data collected, graduating students unanimously consider the EduCITY app to have high educational value as a pedagogical strategy in a science discipline.

The study's results answer the research question, 'What is the relevance of a mobile game-based activity with an AR app for outdoor exploration?' According to the graduating students, the EduCITY strategy has educational value due to its innovative use of mobile technologies in an outdoor learning context. Furthermore, the strategy includes a user-friendly application and significantly enhances the intrinsic motivation of its users, particularly their interest in utilising the application.

However, the students reported that the app had some problems and bugs, and acknowledged that it still requires further adjustments, given that the activity was conducted during the application's testing phase.

Although it is important to exercise caution when interpreting the results of this case study, they are valuable for gaining insights into the features of the EduCITY strategy. These features include: i) resolving the app's issues and bugs; ii) engaging citizens who are not only users but also producers, consumers, and 'owners' of their city; and iii) using an action-oriented transformative pedagogy towards education for sustainability, in line with the principles of open education and education for all.

Overall, it can be concluded that the combination of outdoor environments and new technologies, such as augmented reality, can exponentially enhance the educational effect and result in increased student engagement in science learning.

## ACKNOWLEDGEMENTS

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