EDUCITY MOBILE GAME ACTIVITY AS BEST PRACTICE IN EDUCATION FOR SUSTAINABLE DEVELOPMENT - A CASE STUDY WITH HIGHER EDUCATION STUDENTS (FUTURE TEACHERS)

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Abstract

Technological advances have created opportunities for teachers to integrate technology into the learning process, particularly in science education. The literature suggests the possibility of replacing traditional education formats with mobile and game-based learning due to the emergence of new digital technologies and educational platforms that aim to provide high-quality knowledge. These strategies are considered effective not only in non-formal or informal education but also in formal education, as is the case of the EduCITY app. This app is designed to promote sustainable cities through a smart learning city environment featuring augmented reality (AR) and challenge-based location games. It is fed by a game creation web platform for users without programming skills. Games validated by the EduCITY team become available to all users. This pedagogy encourages learning by doing, using AR mobile games to promote environmental awareness in the city. This paper presents a pilot case study of a pedagogical approach based on exploring a game in the EduCITY app outdoors by higher education students, many of whom aspire to become teachers. The aim is to encourage future teachers with innovative experiences that they can use in their future teaching. The study employed a qualitative interpretive case study methodology and a convenience sample of 28 undergraduate students who were enrolled in the 'Educational Intervention Projects' (EIP) curricular unit during the 2023/24 academic year. The students were invited to play the 'EduCITY on UA Campus' game using the EduCITY app while walking around the University of Aveiro. The game was interdisciplinary and focused on sustainability. The research aims to analyse the perspectives of EIP students on the evaluation of the EduCITY activity as a pedagogical strategy for their future practice. To achieve this, an anonymous questionnaire was administered at the end of the activity to collect data on the students' opinions regarding the overall appreciation of the activity. The data was triangulated with data logs collected on the platform. The data indicates that over than 50% of the students enjoyed using AR, and 60% found the activity innovative and entertaining. Additionally, 70% of the students reported that they gained a better understanding of sustainability and nature. The ease of use of AR received the highest rating from the students. The logs collected indicate that most groups answered the questions correctly. Only 13% of students had more incorrect answers than correct ones. The study highlights EduCITY as an innovative initiative that supports higher education students in learning about education for sustainable development. Furthermore, higher education students, who are future teachers, consider the EduCITY app to be a valuable tool for their future educational practices.

Keywords: Education for Sustainable Development, game-based learning, future teachers, augmented reality, EduCITY.

1 INTRODUCTION

The 2030 Agenda acknowledges sustainable cities and communities as a vital societal objective. Societies worldwide face new challenges due to rapid technological progress and globalization [1]. These challenges include intense urbanisation, such as traffic congestion, waste management, pollution, and the degradation of ecosystem services that societies rely on. To tackle these challenges, it is essential to enable citizens to reflect on their actions and act sustainably in complex situations [1]. Therefore, it is of utmost importance to promote opportunities for developing key competencies in sustainability [2]. Education for sustainable development should play a central role in empowering learners to make informed decisions and take responsible actions for environmental integrity [3].

To attain sustainability, it is crucial to involve citizens who are not only users but also 'owners' of natural and cultural heritage. This can be achieved through a transformative pedagogy that is action-oriented. The pedagogy should include self-directed learning, participation, and collaboration under a social

constructivism approach, problem orientation, and an inter and multidisciplinary approach that links formal and informal learning [1].

Mobile learning frameworks-based games can motivate and enable sustainability-oriented citizen action [4]. They facilitate situated, personal, and collaborative learning [5, 6]. Outdoor games are especially significant for conservation and sustainable attitudes as real-life experiences enhance the ability to comprehend ecosystems, influencing attitudes towards nature [7]. This is in line with the 2030 Agenda's goal 15 - Life on Land.

There is limited research on collaborative learning activities conducted outdoors [8], and as such, their potential to support lifelong learning and contribute to education for sustainability by connecting academia with the community is not well understood.

Mobile devices are a pervasive technology that can support outdoor learning activities, with location-based games being particularly interesting for mobile learning. These opportunities allow students to experience real-life environments outside of the classroom and connect them with the content they are studying in school [9].

Regarding the benefits of using outdoor collaborative learning activities through mobile AR games, EduCITY stands out for its innovative approach to a new action-oriented transformative pedagogy. This approach is essential for developing key competencies for sustainable development. The mobile AR games are based on challenging paths, taking education beyond the classroom and using smart technology. The Smart Learning City Environment, along with this new knowledge and technology-enhanced practical solution, can be replicated in other areas. This challenges conventional thinking about how people can learn about their city and change their habits towards sustainable and resilient cities.

Quiz games that provide immediate feedback, whether the student answers correctly or incorrectly, can be valuable for improving engagement and providing pedagogical benefits if the feedback is constructive and motivational. Game rewards, such as extra points or unlocking the next part of the story, can motivate learners to physically move to the next location (Marfisi-Schottman & George, 2014) and successfully conclude the game, resulting in learning gains. Due to the potential benefits of creating educational mobile games being comparable to those of playing them, and the scarcity of educational resources for AR-based mobile games that incorporate curriculum content, students were allowed to both create and play games developed by the project team.

This paper presents an innovative educational activity using the EduCITY app, which employs a mobile AR app for higher education students aspiring to become teachers. The aim is to provide future teachers with innovative experiences that they can use in their future teaching. The research was conducted to answer the question: 'How do EduCITY activities, based on mobile and game-based learning, promote best interdisciplinary practices for education on sustainable development?'

2 METHODOLOGY

A mixed-method research approach was employed to integrate quantitative and qualitative elements in the analysis of the students' perspectives on the evaluation of the activity as a pedagogical strategy for their future practice. This section comprises three subsections: i) the context of the study; ii) the structure of the 'EduCITY on UA Campus' game; and iii) options for data collection and analysis.

2.1 The context of the study

This paper presents a pilot case study of a pedagogical approach based on exploring a game in the EduCITY app outdoors by higher education students, many of whom aspire to become teachers. The aim is to provide future teachers with innovative experiences that they can use in their future teaching.

The study involved a convenience sample of 28 undergraduate students who were enrolled in the 'Educational Intervention Projects' (EIP) curricular unit during the second year of the Basic Education Degree programme at the University of Aveiro (Portugal) in the 2023/24 academic year. The students were instructed to play the 'EduCITY on UA Campus' game during an EIP class. The students from the previous year were invited to create a game as part of the ‘Integrated Natural Sciences II' curriculum, with a focus on 'Biodiversity and Conservation'. This allowed them to gain experience in game creation and testing.

The 'Educational Intervention Projects' (EIP) is a curriculum unit lasting two semesters and worth 10 ECTS. It involves a group of teachers, each supervising one or two groups of students. The main objective of this

curricular unit is to understand the complexities of educational problems, particularly about the development of educational projects. Despite observation and reflection tasks being common in various educational contexts, students also have the opportunity to attend classes covering diverse topics and providing different experiences. One such topic was exploring the EduCITY app in outdoor settings.

2.2 The structure of the 'EduCITY on UA Campus' game

The game comprised nine points of interest and 24 questions. The objective of the research is to analyse the perspectives of EIP students on the evaluation of the activity as a pedagogical strategy for their future practice.

The students were invited to play the "EduCITY on UA Campus" game using the EduCITY app while walking around the University of Aveiro Campus.

The EduCITY on UA Campus activity takes place on the main UA campus, the Santiago campus. The campus occupies an area of approximately 92 football fields and is located between the Aveiro lagoon area and the city centre. This campus serves as a hub for all educational and research facilities, central administrative services, as well as various supporting amenities, including cultural, sports, and recreational facilities, essentially creating a self-contained "city within the city." Despite its proximity to the city centre, the Santiago campus is surrounded by natural landscapes, including the historic salt marshes that are characteristic of Aveiro.

The UA is affiliated with the Sustainable Campus Network by endorsing the Commitment of Higher Education Institutions to sustainable development. This commitment recognises that universities possess a distinctive blend of skills enabling them to significantly contribute to education, scientific research, social responsibility, and the promotion of the common good. Consequently, members of the network are expected to actively engage in advancing these objectives. In the sequence of this commitment, the EduCITY team has developed a new interdisciplinary game focused on education for sustainable development.

The "EduCITY on UA Campus" game comprises a route with nine points of interest, which any citizen may explore during a tour of the UA campus (Figure 1).

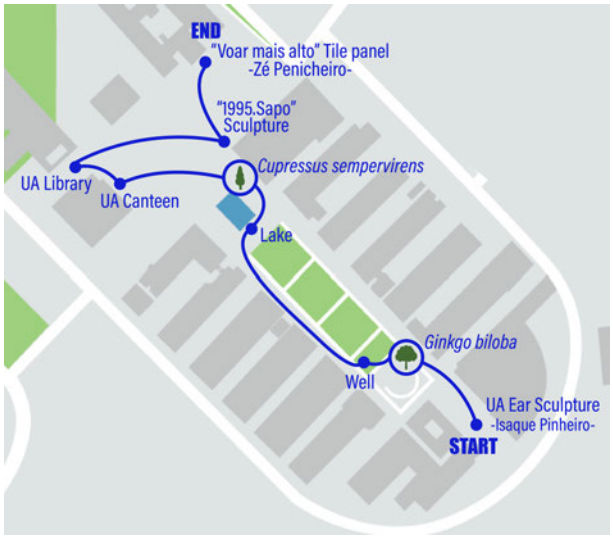


Figure 1. Game map "EduCITY on UA Campus"

The game begins at the UA ear sculpture by Isaque Pinheiro located near the UA Pedagogical Complex (building 23). The second point of interest is the half-moon-shaped amphitheatre where the *maidenhair tree* is located. This tree is marked with an AR marker. Thereafter, one should continue along the campus, passing by the well, the lake, the *mediterranean cypress*, the UA canteen and library and the "Sapo sculpture" by Paulo Neves. The game ends at the tile panel "Voar mais alto" by Zé Penincheiro.

Along the path, the students responded to 24 multiple-choice questions about Science, Math, History, and Citizenship Education. This quiz game was enriched with augmented reality (AR) and other multimedia resources, such as videos and images, to promote student learning. Considering the influence that multimedia resources have on student learning, it was considered pertinent to include these resources in

the game to assess the impact of their use in outdoor teaching and learning environments. In light of the aforementioned considerations, it was necessary to develop the following elements for each question: i) question introduction; ii) image, video, or audio (multimedia resources); iii) question formulation; iv) four answer options; v) feedback for correct and incorrect answers; vi) multimedia resources for the feedback (in some cases); vii) AR marker; and viii) instructions to find the point of interest.

Figure 2 shows the game template. Figure 2A shows the game's welcome message, which can be edited and is specific to each game. In figure 2B, the mascot of the project, the flamingo, gives instructions to reach the half-moon point of interest. Figure 2C illustrates the introduction of a question with AR, while Figure 2D presents the question and four answer options. Figure 2E shows constructive feedback after the team answers the question correctly.

Figure 2. Game illustrative screens

The objective of this game is to positively influence students' attitudes towards nature conservation. The game focuses on four key topics: (a) the impact of noise in cities, (b) the importance of green spaces and their conservation, (c) the value of water and the water footprint, and (d) awareness of food waste. The students are encouraged to walk a path, observe the outdoor context, and learn about these concepts (Figure 3).

Figure 3. Students at UA playing the game "EduCITY on UA Campus" integrated into the CITY app

Following the conclusion of the game, the students were invited to complete a post-game questionnaire. The event concluded with the presentation of small prizes to the teams that had demonstrated the most impressive performance. However, all students were presented with a participation award.

2.3 Data collection and analysis

This paper addresses the research question: 'How do EduCITY activities, based on mobile and game-based learning, promote best interdisciplinary practices for education on sustainable development?'. To this end, the study gathered students' opinions on their overall appreciation of the EduCITY activity through an anonymous questionnaire administered after the activity. This data was triangulated with

data logs collected on the EduCITY platform. The objective of this data triangulation was to enhance the understanding gained from the closed and open-ended questions gathered from the questionnaire and the students' game performance gathered from data logs.

Regarding the data logs, it should be noted that after each game, a log file is automatically uploaded to the EduCITY platform. This log file is then downloaded as an Excel file. In order to analyse the students' game performance, a data restructuring was required to examine the performance of each group of students (Graph 1) with the frequency of correct and incorrect answers per group. Furthermore, the frequency of correct versus incorrect answers was analysed for each question (Graph 2).

The questionnaire comprises three sections (A, B and C), each leading to different analyses. Section A is dedicated to evaluating the activity in the promotion of education for sustainability, section B contributes to the interpretation of the respondents' evaluation of the app, and section C refers to the global appreciation of the activity. In this study, only section C is analysed according to the research question. Section C is divided into two distinct analytical categories: quantitative (section C.1) and qualitative (sections C2 and C.3). The quantitative analysis employs a combination of closed-ended questions and a 6-point Likert scale, ranging from " Disagree very strongly" to "Agree very strongly", to elicit responses (Graph 3).

A qualitative analysis was conducted using open-ended questions to elicit responses regarding the students' likes, dislikes, and opinions of the activity (section C.2) and concrete examples of learning gained through the game-based activity (section C.3). This prompted a qualitative interpretation of the students' perceptions, which were collected into an Excel file. The answers were grouped into four categories: i) "What students liked most about the activity", ii) "What students liked least about the activity", iii) "Opinion about the EduCITY activity", and iv) "A concrete example of the knowledge acquired by the students as a result of the activity". The key aspects of the students' answers were grouped according to the categories illustrated in Table 1.

To ensure anonymity and maintain voluntary participation throughout the data collection process, the questionnaire was anonymous..

3 RESULTS AND DISCUSSION

This section presents the core findings of the study, which examine the impact of the EduCITY on the UA Campus game on students learning in the domain of sustainability. The results are analysed to determine whether engaging with the game facilitated a more profound comprehension of sustainability concepts.

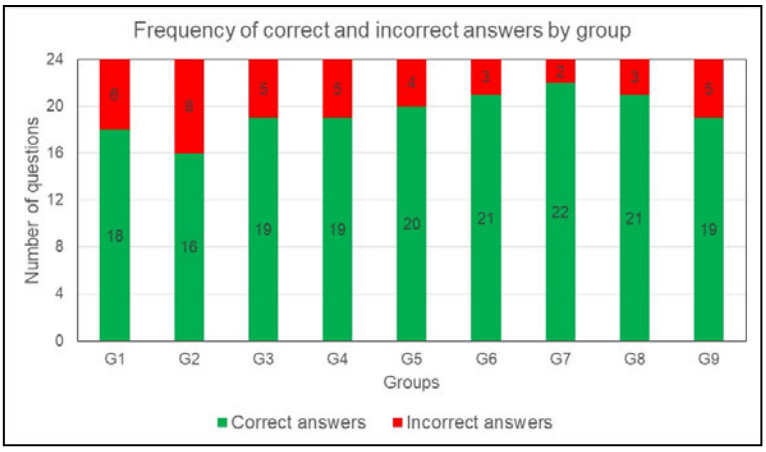
3.1 Students' Game Performance

The students' performance in the game was evaluated from two perspectives: the frequency of correct and incorrect answers by group (Graph 1) and the frequency of correct and incorrect answers per question (Graph 2). The first data was collected on paper by the monitors who accompanied the students during the activity, while the second analysis corresponds to the data collected from the log file uploaded to the EduCITY platform when the students finished their games.

Graph 1 illustrates the frequency of correct and incorrect answers per group in the "EduCITY on UA Campus" game. The groups are identified by Group 1 to Group 9, and each bar represents the frequency of answers in each category (correct and incorrect) of 24 questions.

Overall, the majority of groups demonstrated a high level of proficiency in the game, with a higher frequency of correct answers than incorrect ones. Groups 5, 6, 7 and 8 exhibited notable performance, achieving a commendable number of correct answers. This indicates that the game effectively facilitated learning and knowledge retention of sustainability topics. While the overall trend is positive, there is also noteworthy variability in performance between groups. The highest number of correct answers (22), was achieved by Group 7, while the lowest (16) was recorded by Group 2.

The results of the statistical analysis corroborate these observations. The average number of correct answers per group is 19.44 (19 correct answers), with a standard deviation of 1.81. This suggests that most groups performed around the average, with moderate variability. The median of 19 correct answers supports this idea, while the mode of 21 correct answers in groups G6 and G8 indicates that these groups performed slightly above average. The G7 groups achieved a score of 22 out of 24, demonstrating exceptional performance compared to the other groups.



Graph 1. Frequency of questions incorrectly and correctly answered by groups of students

A second analysis was conducted to infer the frequency of correct and incorrect answers per question (Graph 2). However, as previously stated, this data was collected from the log file in the EduCITY platform after each game. Consequently, it is necessary to upload the results into the platform, which requires an internet connection. The number of groups represented in graphs 1 and 2 differs because one group was unable to submit their results to the platform due to a lack of internet connection. This represents a limitation of our app prototype.

Graph 2. Frequency of incorrect and correct answers per question

Graph 2 presents a summary of the questionnaire results per question. It shows that the majority of students (five groups) were unable to answer the following questions correctly:

- Question 1.1 was designed to assess participants' observational skills and environmental knowledge. This question employed audio as a multimedia resource. Students were asked to identify the bird they were listening to. Many students were unable to recognise the sound of a flamingo and provided incorrect responses;
- Question 1.2 tested students' ability to use the noise EduCITY sensor outdoors and respond to the following prompt: "Using the noise sensor, try to understand the range of sound pressure values to which the noise of a quiet conversation corresponds". To answer correctly, students

needed to demonstrate both focus and critical thinking skills. Many students exhibited disruptive behaviour, which hindered their ability to provide accurate responses;

- Question 4.3 tested students' knowledge about animal behaviour, with the question “Do freshwater fish drink water?”. In this question, no resources or AR were applied, which may have influenced the high frequency of incorrect answers.

The analysis showed that there was a difference in performance for different question types based on the method of information acquisition.

Multimedia resources were present in 50% of the questions (Q1.1, Q2.1, Q2.2, Q3.1, Q3.2, Q4.1, Q4.2, Q5.1, Q5.2, Q5.3). In terms of the questions, 16% (Q2.2, Q5.1) were joined with AR, which provided students with greater insight. The overall scores of the questions that employed AR and/or multimedia resources were well-positioned. However, it was anticipated that the scores for the questions that used both AR and multimedia resources would be above average, which did not occur. Only 8% (Q2.2) of those questions achieved that goal. This is possible since the other 8% (Q5.1) of those questions that had both AR and multimedia resources caused confusion or misled students. Therefore, it is necessary to conduct this analysis so that in future games, the AR and multimedia resources can be aligned and non-overlapping, thus ensuring that students have the correct perception to understand and answer correctly.

The results indicated that students demonstrated lower correct response rates for question types that required searching and retrieving textual information in AR content (Q5.1), as well as observing their surroundings. However, it is worth noting that some questions within these categories (Q1.3, Q2.2, Q3.2, Q5.3, Q6.3, Q6.4, Q8.1, Q8.2, Q9.1, and Q9.3) received successful responses from all student groups. The data suggests that the difficulty of a question is not inherent to its type, but rather depends on the specific content of the question.

Additionally, the data indicates that performance is superior on questions that involve the use of resources such as videos, audio, and images, as well as on questions related to nature and the UA campus. However, some of the completely successful responses employed the use of both tools to support the question for the participants, which suggests that this learning modality may be a preference among students and/or game players.

These differences can be attributed to several factors. Firstly, students with a stronger foundation in sustainability concepts might have navigated the game more efficiently. Secondly, effective group collaboration likely played a role in successful problem-solving and knowledge-sharing. Lastly, strategic approaches may have also contributed to the observed differences. Groups that developed and implemented effective strategies to overcome challenges within the game would have gained an advantage.

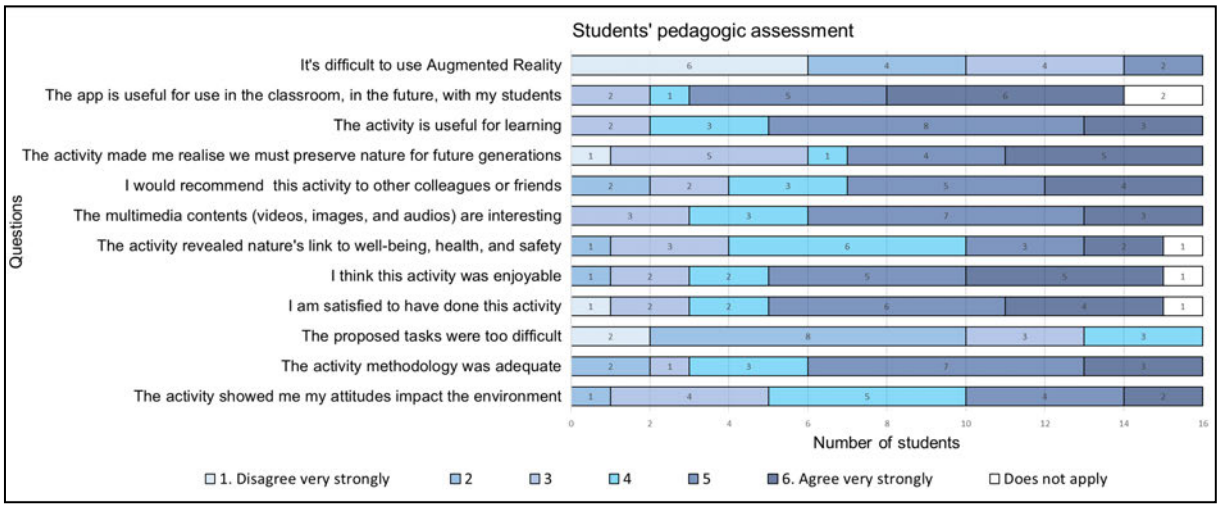
3.2 Students’ Perceptions of the EduCITY App and Activity

The perceptions of students regarding the activity and the EduCITY app were examined through the analysis of data collected in section C of the questionnaire. The analysis was divided into two categories: quantitative (questions of section C.1, Graph 3) and qualitative (questions of sections C.2 and C.3, Table 1).

Graph 3 examines students’ perceptions of the EduCITY app and associated activities, with a particular focus on the promotion of education in the field of sustainable development. It is important to note that the questionnaire included both positive and negative statements. Graph 3 shows a generally positive perception of the game, with most respondents strongly agreeing with positively phrased statements and strongly disagreeing with negatively phrased ones. This suggests that the game effectively promoted a positive learning experience in sustainability concepts.

The data analysis revealed several statements that received the highest level of consensus among the respondents. For example, 11 participants agreed or strongly agreed with the statement 'The app is useful for use in the classroom, in the future, with my students', which relates to the activity's effectiveness in demonstrating how enjoyable and effective learning can be when combined with technology. The EduCITY is designed to enhance teaching methodologies and promote fast game-based learning for future teachers. Ten participants expressed disagreement or strong disagreement with the statement 'It’s difficult to use augmented reality', suggesting that the use of AR was presented clearly and was not confusing or difficult. This analysis leads to the conclusion that integrating AR into the EduCITY app has the potential to enhance motivation for learning and facilitate authentic learning experiences. The questionnaire results indicated that over half of the students found AR enjoyable, with

60% viewing it as both innovative and entertaining. Furthermore, students rated the ease of use of AR as the highest among the various platform features.



Graph 3. Global motivation appreciation of the EduCITY activity

In the sentence "The activity made me realise we must preserve nature for future generations", nine students indicated that they agreed with the statement, either strongly or very strongly. This indicates that the students recognised the value of the activity in terms of nature preservation. In terms of the impact of students' attitudes on the environment, twelve students indicated either a very strongly or strongly agreement, suggesting a tendency for students to perceive the activity as promoting sustainability-related values and a positive perception of the awareness-raising potential of the game-playing activity concerning environmental sustainability attitudes.

In terms of qualitative analysis of the open-ended questions regarding the EduCITY app and the activity, Table 1 presents the categories and subcategories defined after analysing the answers to the open questions in the questionnaire. These categories are as follows: i) what students liked most about the activity, ii) what students liked least about the activity, iii) opinion about the EduCITY activity, and iv) a concrete example of the knowledge acquired by the students as a result of the activity.

The subcategories are as follows: i) learning about the context they observe (natural and cultural heritage), ii) augmented reality feature, iii) teamwork, iv) the activity in general, v) weather conditions, vi) technical problems, vii) some of the game's features, viii) interesting, ix) innovative, x) fun, xi) educational, xii) reasonable, xiii) the sounds of flamingos, xiv) facts about food waste in the University of Aveiro canteen, xv) curiosities about the physical space of the University of Aveiro, xvi) facts about wasted water. Several students did not respond to the open-ended questions.

As illustrated in Table 1, the students indicated that they found the learning about the context they observe (natural and cultural heritage) to be the most enjoyable aspect of the activity. Eleven students expressed a preference for learning about the context they observe (natural and cultural heritage), particularly about the UA Campus and the natural species around it. Eight students mentioned that they enjoyed the activity in general, while six students indicated a preference for the augmented reality feature. Two students revealed that they enjoyed playing as a team.

Regarding the aspects of the activity that students found least appealing, the majority of students (12) cited the weather conditions and certain game features, particularly the lack of verbal communication from the flamingo character, which differed from the monkey's communication style in EduPARK (A13, A14, A21). This observation can be attributed to the fact that these students had prior experience with the EduPARK project, which was a second-year degree course.

The students perceived this activity to be interesting (11), innovative (6), educational (4), enjoyable (3) and reasonable (2). Furthermore, the students provided an illustrative example of the knowledge they had acquired through this activity. The majority of students indicated a keen interest in the physical space of the University of Aveiro. Furthermore, the students indicated that they had previously been unaware of several facts, including the fact that the search tool "Sapo" was developed at the University of Aveiro (A9, A12, A16, A19, A29), that some plant species on the UA campus had been identified (A2,

A6), and that there were carps on the UA campus (A6, A22). Additionally, nine students indicated that they had acquired knowledge about the authentic sound of flamingos (9). Furthermore, the students reported that they had gained insight into the facts regarding food waste in the University of Aveiro canteen (2) and the issue of wasted water (2).

Table 1. Qualitative analysis of the open-ended questions regarding the EduCITY app and the activity

Category	Sub-category	Example citation	Total	
What students liked most about the activity	Did not answer		4	
	Learning about the context they observe (natural and cultural heritage)	I participate and learn more about the trees on campus (A1), learn about the role of nature in urban spaces (A2), see details I've never seen before (A9), learn about the UA (A10), get to know the campus better (A11), the combination of nature and technology (A20), I have the opportunity to learn outside the classroom (A24), I learn new knowledge related to the nature of UA (A25), I learn more about the UA and nature (A26), some curiosities I learnt about (A29), knowledge about UA that I have acquired (A30)	11	28
	Augmented Reality feature	The augmented reality on the DEP tile (A4), using augmented reality (A6), see augmented reality on a tile (A8), using augmented reality (A13), having activities with augmented reality (A21), using augmented reality (A22)	6	
	Teamwork	Helping colleagues (A15), working as a team (A30)	2	
	The activity in general	Take part in this activity (A7), diversity [of the activity] (A12), the end of the game (A16), discovery dynamics (A17, A27), being a different activity from what we're used to (A18), having questions that made us think and reflect (A19), doing this activity, which is quite innovative and playful (A28)	9	
What students liked least about the activity	Did not answer		8	
	Weather Conditions	[...] to play in the rain (A1, A12, A18, A19, A25, A26, A28, A30), the weather (A2, A6, A16, A20)	12	23
	Technical Problems	When the APP crashed (A4), Augmented reality wasn't working properly (A7, A8), app's bugs (A29)	4	
	Some of the game's features	Some questions are not very clear (A10, A11, A12), the flamingo character doesn't speak like the monkey did in EduPARK (A13, A14, A21), no feedback with videos or more interactive answers (A24)	7	
Opinion about the EduCITY activity	Did not answer		4	
	Interesting	-	11	26
	Innovative	Fresh and innovative for children (A20)	6	
	Enjoyable	Fun to learn about the campus and its history (A8)	3	
	Educational	Good to use later with my students (A19), an incredible tool for education (A29)	4	
	Reasonable	-	2	
A concrete example of the knowledge acquired by the students as a result of the activity	Did not answer		4	
	The sound of flamingos	-	9	28
	Facts about food waste in the University's canteen	I learnt that there is food waste in the UA canteen (A28)	2	
	Curiosities about the physical space of the University of Aveiro	That the search tool 'sapo' was created at University of Aveiro (A9, A12, A16, A19, A29), some plant species on the UA campus (A2, A6, A15, A18, A27), that there were carps on the UA campus (A6, A22), I have enriched my knowledge of my surroundings within the UA (A8, A23)	15	
	Facts about wasted water	The exorbitant amount of water used to produce a pair of trousers and meat (A5), excessive water consumption (A30)	2	

It is important to emphasise the significance of outdoor environments in this activity. The questionnaire's open-ended section revealed that students derived pleasure from learning within the UA's outdoor setting since 9 students mentioned that what they liked best was getting to know the UA campus better. Therefore, implementing the teaching method in an outdoor space, not only fosters the development of healthy lifestyle habits but also promotes contextualised learning. This approach encourages participants to actively observe their surroundings. Finally, the students were asked to provide specific examples of the sustainability principles they learned during the activity. The knowledge acquired by the students was mainly focused on the University of Aveiro, food waste problems, and interesting facts such as the sounds made by flamingos.

4 CONCLUSIONS

This paper presents a pilot case study of a pedagogical approach based on exploring the "EduCITY on UA Campus" game in the EduCITY app outdoors by higher education students. A summary of the results indicates that the 28 undergraduate students who participated in this study achieved satisfactory

performance in the game. Furthermore, 70% of the students reported that they gained a better understanding of sustainability and nature. Most students also demonstrated a positive perception of the sustainability learning value of the game, as evidenced by the examples they provided to illustrate new learning about sustainability achieved with the EduCITY activity.

The analysis revealed performance differences among students based on question types and methods of information acquisition. While questions requiring textual information retrieval and observation of surroundings generally yielded lower correct response rates, exceptions were observed where all student groups responded successfully. This indicates that question difficulty is not inherent to its type but rather depends on specific content.

The evidence presented thus far suggests that the use of AR in the EduCITY platform has the potential to enhance motivation to learn, while simultaneously supporting authentic learning. The data indicates that over 50% of students expressed enjoyment in using AR, with 60% of respondents perceiving the activity as innovative and entertaining. Furthermore, the ease of use of AR received the highest rating from the students. It is also essential to emphasise the significance of the outdoor space in this activity. In the open-ended question of the questionnaire, the students indicated that they derived enjoyment from learning in the University's outdoor context. Thus, the implementation of the pedagogical approach in an outdoor setting also encourages the development of healthy lifestyle habits and contextualised learning, as it is necessary for players to observe their surroundings [8].

This paper contributes to the literature on mobile game-based AR learning by presenting empirical evidence regarding the effectiveness of integrating new technologies in higher education to promote student learning. It also provides an example of an innovative education experience that encourages future teachers to use it in their future teaching. Furthermore, the study reports on a pilot case study of a pedagogical approach that comprises a highly useful tool for teachers and students to explore scientific knowledge by accessing appealing information on environmental awareness in the city. This game is available for free on the EduCITY app.

Future research will involve further EduCITY activities to collect data which will be analysed to ascertain the extent to which EduCITY promotes changes in citizens' knowledge, skills, values and attitudes, thereby empowering them for sustainable development.

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