EDUCITY APP USER EXPERIENCE: SCHOOL STUDENTS' PERSPECTIVE

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Abstract

The literature highlights Mobile Augmented Reality Games (MARGs) as effective tools for enhancing k-12 students' learning, fostering cognitive and emotional development, and innovating educational practices. However, challenges like technical constraints, expenses, and accessibility, hinder their widespread adoption. Despite their potential, MARGs remain underutilised in educational settings, possibly due to the scarcity of reliable educational materials. Hence, there's a pressing need to develop educational MARGs, particularly, for sustainable development education. The primary goals of EduCITY projects are to foster knowledge and facilitate new approaches for citizens to actively contribute to the city's sustainability. Consequently, the project team has developed a smart learning city environment, comprising a mobile application and a web-based platform for collaborative creation by MARG users, including students and educators, who lack programming expertise. Hence the necessity to evaluate the user experience (UX) of the prototype EduCITY application. This research survey explores the user experience (UX) of the EduCITY app prototype among 82 students in the 7th to 11th grades from Aveiro, following their participation in an outdoor game-playing activity. Data collection used a self-administered questionnaire focusing on the review of the EduCITY app, with analysis conducted using a User Experience Questionnaire (UEQ) software. Results were analysed through various methods, including mean value comparison, benchmark evaluation, and confidence assessment of different quality parameters. The results' analysis of the app evaluation demonstrated notable strength in "Attractiveness" and "Stimulation" but also revealed areas for improvement, particularly in "Dependability" and "Novelty". This study indicates a growing recognition among students regarding the significance of MARGs in education, aligning with Goal 4 of the 2030 Agenda for Sustainable Development.

Keywords: MARGs, k-12 students, mobile learning, game-based learning, user experience (UX), sustainable development, UEQ, EduCITY.

1 INTRODUCTION

The effectiveness of Mobile Augmented Reality Games (MARGs) in enhancing learning outcomes for k-12 students has been explored in the literature. Research findings indicate that MARGs can create meaningful learning environments and foster key competences for the 21st century, such as problem-solving and critical thinking particularly within primary education settings [1]. Also, a study of the game "School Scene Investigators" for 8th graders indicated that engaging in narrative-driven, inquiry-based science games has the potential to boost science interest among individuals of all genders. Moreover, participants demonstrate perseverance when faced with challenges during gameplay, and upon achieving success, they exhibit a desire for even more challenging tasks [2].

The adoption of such methodologies in education holds promise for enhancing science education effectiveness compared to conventional teaching approaches. For example, in a quasi-experimental study by Wang [3], students showed higher levels of engagement, academic performance, and satisfaction in the game-based learning group compared to the book-based learning group. This pedagogical approach has been found to enhance students learning of physics, by using augmented reality to make difficult concepts easy to understand [3]. The integration of mobile and game-based learning methods also proves to be advantageous in enhancing students' spatial intelligence and knowledge acquisition [4]. Moreover, collaborative gameplay in MARGs has been found to have a greater impact on emotional affection, social interaction, and interest [5]. Among the benefits of MARGs, it has been pointed to the facilitated access to information, the fun learning they may provide, and even the diversification of teaching strategies in the classroom [6]. Other benefits include improving students' motivation, and engagement,[1][2][5][7], self-efficacy, and immersion [5].

Despite the advantages associated with MARGs, educators and students could encounter a learning curve when incorporating them in educational settings [8]. Educators might necessitate training to

effectively merge the technology into their instructional methods, while students may require time to adjust to the new educational landscape. Numerous barriers were identified in the research, including technical constraints, high costs of the associated technologies, and challenges related to accessibility [6]. Technical challenges such as internet network delays, device compatibility issues, and software glitches have the potential to limit a seamless exploration of augmented reality (AR) utilized in education [8][9]. A large-scale study investigation [10] revealed that the scarcity of devices and connectivity problems act as barriers to the adoption of MARGs in educational contexts. Furthermore, ensuring alignment between MARGs and the curriculum emerges as a pertinent concern in educational environments. The availability of educational augmented reality games may be constrained, particularly in certain subject areas or age groups. Moreover, the options for customization within existing games might be restricted, posing challenges in aligning game content with specific educational objectives. Limitations such as the necessity of an internet connection, the sluggishness of mobile devices, and regulations prohibiting the use of mobile devices in schools due to potential distractions further compound the issue [8].

Another factor that may be hindering the wide adoption of MARGs in educational settings is the lack of readily available free content and the recurrent discontinuation of authoring tools and applications [11]. Also, it was identified a need for research focused on the advancement of MARGs aligned with the curriculum, as they have the potential to promote learning valued in school systems [12]. In this context, the EduCITY project created a smart learning city environment to foster education for sustainability through innovative pedagogies and technologies [13]. Specifically, the project developed an app that sustains the exploration of MARGs in city settings and provides challenges and interactive experiences that engage learners in exploring and understanding their surroundings while promoting sustainable practices. The games available in the app are co-created in a web platform by citizens without programming skills and are developed for different target groups of the public (school students, higher education students, tourists, etc.) [13].

In previous work, the EduCITY app prototype was tested with doctoral students aiming to understand their perspective on these innovative approaches[14]. The results showed that “Dependability” and “Efficiency” were the quality attributes that were classified as “bad” or “below average” in the benchmark analysis and mean evaluation, being the dimensions that required improvements. In addition, these results reflect the view of doctoral students in education, who answered the questions of the questionnaire based on their knowledge about the suitability of the app for elementary school students. Hence, there is a need to collect the views of other educational stakeholders, particularly the perceptions of the app's target audience, non-higher education school students, to understand their app experience. The research question is: How do school students evaluate the user experience of a prototype app that integrates mobile and augmented reality games?

The remainder of this paper is organised into two main sections: methodology and results & their discussion. These sections will provide a concise overview of the survey conducted [15], materials used, in particular the User Experience Questionnaire (UEQ) [16], and key findings. A concluding section will then summarize the main points of this work and limitations encountered and, also, potential areas for future exploration and improvement are highlighted.

2 METHODOLOGY

Promoting knowledge and creating new opportunities for citizens to contribute to the city's sustainability are the main objectives of the EduCITY project. Therefore, the project team developed a smart learning city environment, including a mobile app and a web-based platform for MARG co-creation by users without programming skills, such as students and teachers from several school levels. Therefore, there was a need to evaluate the user experience of the EduCITY app prototype.

This research followed a survey methodology, which involved collecting quantitative and qualitative data by implementing a questionnaire to students who participated in the study. This approach enabled the inclusion of a diverse range of participants, allowing data collection at a faster rate than other methods [15]. Data was collected in 5 activities with students from the 7th to the 11th grades of different Portuguese schools, as shown in Table 1.

Table 1. Program of activities for data collection

Date	*Activity of playing the game*	*Portuguese School*	*School level*	*Participants*
The morning of the 20th of April of 2023	"EduCITY no campus da UA"	Escola Secundária José Estevão, Aveiro	10th	27
The morning of the 27th of April of 2023	"EduCITY no campus da UA"	Escola Básica e Secundária de Murça, Vila Real	7th, 8th and 9th	35
The afternoon of the 27th of April of 2023	"EduCITY no campus da UA"	Colégio Nossa Senhora da Esperança, Porto	7th and 8th	86
The morning of the 28th of April of 2023	"UA Informa"	Agrupamento de Escolas de Cinfães, Viseu	11th	10
The morning of the 26th of May of 2023	"Recursos naturais por Aveiro"	Escola Secundária José Estevão, Aveiro	8th	28
			Total	186

In each activity, students played their respective games, using the EduCITY app prototype, while being monitored by their teachers and members of the EduCITY team. At the end of every activity, students filled in a self-ministered paper questionnaire with specific questions regarding four different sections (A to D).

"Section A" focuses on assessing students' perceptions of the EduCITY activity value in promoting sustainable development. "Section B" integrates the UEQ, a tool that allows a fast and immediate evaluation of the user experience with a specific software [16], in this study the EduCITY prototype. In this section, respondents are prompted to express their opinion regarding 26 items of quality aspects that form six scales, with the following organization [16]:

- Attractiveness;
- Pragmatic quality (goal-oriented)
  - Perspicuity;
  - Efficiency;
  - Dependability;
- Hedonic quality (not goal-oriented)
  - Stimulation;
  - Novelty.

Hence, in section B, each item has pairs of contrasting attributes that may apply to the app (e.g., annoying / enjoyable). The circles between the attributes represent gradations between the opposites. Participants are invited to express their agreement with the attributes by ticking the circle (from 1 to 7) that most closely reflects their impression.

Finally, "section C" comprises qualitative methods for exploring the participants' global evaluation of the activity, while "section D" is about a brief profiling of participants.

In this study, the analysis is focused in "section B", and it is made using the UEQ Excel software developed by Schrepp and colleagues [16].

The questionnaire was voluntary, so from the total of 186 students participating in the activities, only 132 filled in the questionnaire. After collecting the data, we inserted it into the Excel software "UEQ_Data_ Analysis_Tool_Version12" (downloaded from the site www.ueq-online.org at https://www.ueq-online.org/ Material/ Data_Analysis_Tools.zip, accessed on 21 August 2023).

2.1 Data analysis

The UEQ_Data_Analysis_Tool_Version12 automatically outputs scale values, bar charts, and other basic statistical indicators. It was designed by Schrepp and colleagues [16] to give information about the user experience of specific activities or/and products. The Excel is divided into several worksheets, which contain information about the data of the questionnaires:

- **Data**: Enter raw data from the questionnaires;
- **Transformed Data**: Transformation of the answer range and evaluation of each 6 scales;
- **Results**: Main results of the questionnaires. Calculation of the scale and standard deviation means;
- **Confidence Intervals for Items and Scales**: Confidence intervals for the scale mean and for the mean of each item;
- **Distribution of Answers per Item**: Distribution of the answers for the single items. Finding items that show a polarisation of opinions;
- **Correlations of the Items per Scale and Reliability Coefficients**: Calculation of the Cronbach-Alpha Coefficient and Guttmans Lambda2 Coefficient per scale;
- **Benchmark**: Presentation of how good the evaluation of the product is compared to the products in the benchmark data set;
- **Detect Suspicious Data**: Search for inconsistencies in answers from participants who answer at least a part of the items randomly;
- **Sample Size to Reach a Certain Precision Concerning the Estimated Scale Means**: Estimation of how much data you need to reach a certain precision;

Despite having many worksheets, we decided to select and discuss only the ones that could give us more insight into the evaluation of the user experience of the app. Thus, we chose “Data”, “Transformed Data”, “Detect Suspicious Dada”, “Cronbach’s Alpha-Coefficient”, “Results” and “Benchmark Evaluation”. The last two will be approached in the section “Results and Discussion” of this article.

2.1.1 Data

Here we entered the respondents’ answers (varying from 1 to 7) related to each item (1 to 26). In case of an empty cell (the participant did not answer), we left it empty, so it would not cause errors in the calculations, as indicated in the UEQ Data_Analysis_Tool_Version12.

2.1.2 Transformed Data

The order of the positive and negative terms for an item is randomized in the UEQ. Per scale, half of the items start with the positive term and another half with the negative term.

To statistically analyse the answers, we needed to transform the 1 to 7 answer options into a bilateral (for example, according to error bars). Therefore, the worksheet automatically transforms the values per item, where +3 represents the most positive and -3 is the most negative value (which also corresponds to 7 possible answers).

In addition, this worksheet gives the first evaluation of the scale means per participant, where each scale is related to specific items.

2.1.3 Detect Suspicious Data

In the UEQ, there is a real probability of the participants answering randomly, so it was imperative to detect suspicious data with pattern techniques and remove them from the data set.

This worksheet employs a straightforward heuristic based on the disparity between the most and the least favourable responses to the items constituting a particular scale. If a substantial difference (>3) is detected, it is interpreted as a potential indication of irregular data patterns. Nonetheless, such occurrences are not uncommon and can result from random response errors or misunderstandings of an item by the respondents. Therefore, it is not advisable to disregard a response solely based on this criterion for a single scale. However, if this pattern persists across 2 or 3 scales, it suggests potentially dubious responses, prompting the removal of the dataset associated with that particular respondent. To provide that information, this worksheet has a table related to the scales with inconsistent answers. This was made in the assumption that if the column called “Critical?” had values >3, the data from that

respondent was removed from the big set. Following this procedure, 32 questionnaire responses (24%) were deleted in this study.

Furthermore, there is another technique in this worksheet to evaluate the data quality, and this second heuristic is based on the number of identical answers (in the original worksheet “Data”). If a participant, for example, crosses for all items in the middle category ("4") this can hardly be accepted as a serious response. Such answers are most likely the result of an attempt to finish the survey quickly. It is suggested by Schrepp and colleagues [16] the deletion of the corresponding data that in the table “Critical length of the Same answer for” have a value greater than 15, which means that a participant selected the same answer option more than 15 times. Following this procedure, 11 respondents' answers (11%) were deleted in this study. Additionally, the 7 respondents who did not answer section B, were also removed.

Given those evaluations, we removed the suspicious data from the original worksheet “Data” and proceeded to interpret the results of 82 respondents, which corresponds to 44% of all activity participants.

2.2 Cronbach’s Alpha-Coefficient (CAC)

Analysing the internal consistency of the data is crucial to have a high correlation between the items that belong to the same scale. To proceed with a measure of the consistency of a scale, we calculated the Alpha-Coefficient, Table 2.

Table 2. Cronbach’s Alpha-Coefficient (CAC) for the scales means

Scale	***Cronbach’s Alpha-Coefficient (CAC)***
Attractiveness	0.89
Perspicuity	0.82
Efficiency	0.77
Dependability	0.43*
Stimulation	0.89
Novelty	0.60*

**Results of the scales that need to be analysed with caution.*

A high CAC indicates a strong correlation between items within the same scale. As shown in Table 2, all scales except “Dependability” (CAC=0.43) and “Novelty” (CAC=0.60) achieved a CAC above the recommended threshold of 0.7 [17]. This suggests potential issues with the reliability of these two scales, where some items might be misinterpreted by users during this evaluation.

3 RESULTS & DISCUSSION

This section presents and discusses the results regarding data collected with the UEQ, from 82 students from year 7 to year 11 to evaluate their user experience with the EduCITY app prototype. The results were produced with the UEQ Excel software and its worksheets “Results”, “Benchmark Evaluation” and “Cronbach’s Alpha-Coefficient”.

3.1 Results: UEQ scale means and variance

Figure 1 presents the scales mean and respective variance obtained from all the valid students’ responses (82 respondents). Figure 1 indicates that all scales achieved an evaluation above average, with “Attractiveness” being the strongest.

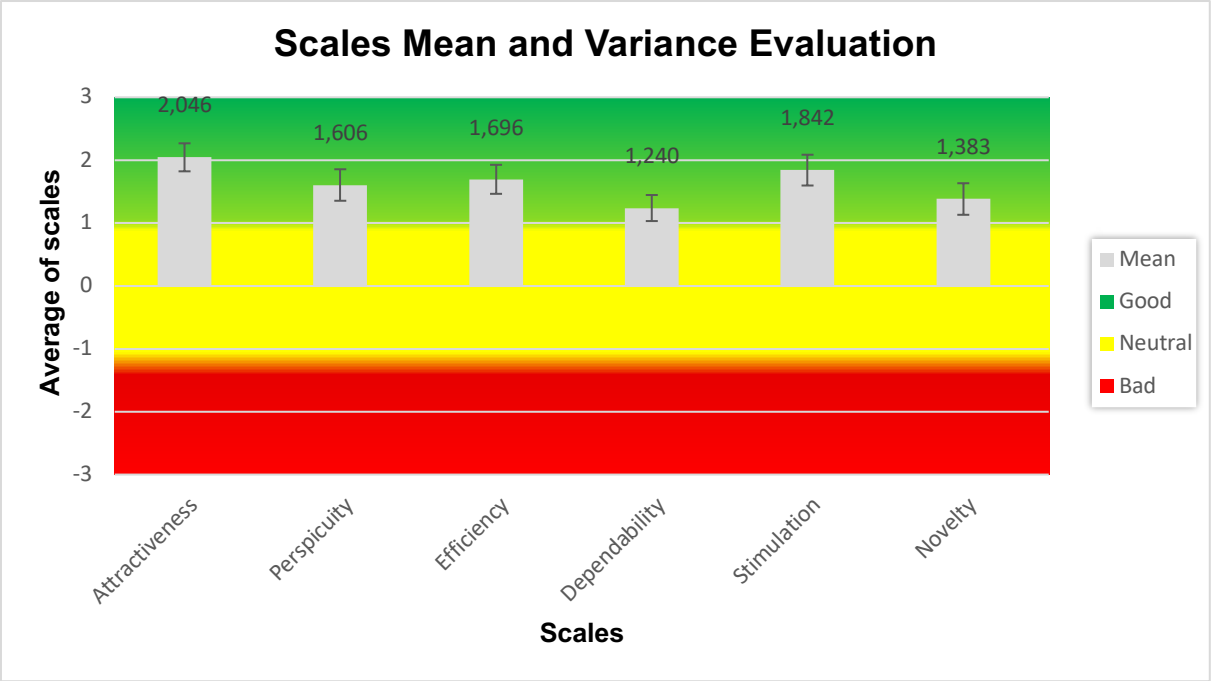

Figure 1: Scales Mean and Variance Evaluation.

The authors of the UEQ_Data_Analysis_Tool_Version12 consider that “values above +1 indicate a positive impression of the users” and “a value near +2 represents a very positive near optimal impression of the participants”, due to the avoidance of the extreme effect [17]. Therefore, a qualitative method was applied based on colours for the average of scales:

- Good (1≤mean≤3)
- Neutral (-1≤mean≤1)
- Bad (-3≤mean≤-1)

Crossing the results presented in Figure 1 with those presented in Table 2, we find that the high mean values of "Attractiveness" (2.046, in Figure 1) and "Stimulation" (1.842, in the same Figure) can be considered reliable, as these scales achieved high CACs (CAC=0.89 for both in Table 2), witch point to a high level of confidence in these results.

The same reasoning can be applied to the "Dependability" (mean = 1.24 and CAC = 0.43) and "Novelty" (mean = 1.38 and CAC = 0.60) scales, which achieved the lowest values. As the respectives CACs are the lowest values, and bellow the reference value for reliable results (0.7), it can be interpreted that these low mean values for "Dependability" and "Novelty" may not be reliable. It should be noted that "Dependability" is concerned with the items "secure/not secure", "predictable/unpredictable" and meeting user expectations. The questionnaire item "secure/not secure" may require improvement for clearer interpretation. Additionally, both "predictable/unpredictable" and "meets expectations/does not meet expectations" appear to be interrelated. By enhancing the app's design and content, we can address these aspects and potentially improve the "Novelty" scale as well. This could entail the incorporation of novel concepts and greater originality, to move software away from being classified as "usual" and closer to "leading edge" (item “usual/leading edge”).

As the scales can be grouped into three qualities: attractiveness, pragmatic quality (Dependability, Novelty, Efficiency, Perspicuity) and hedonic quality (Stimulation, Originality), Figure 2 presents the means for these qualities.

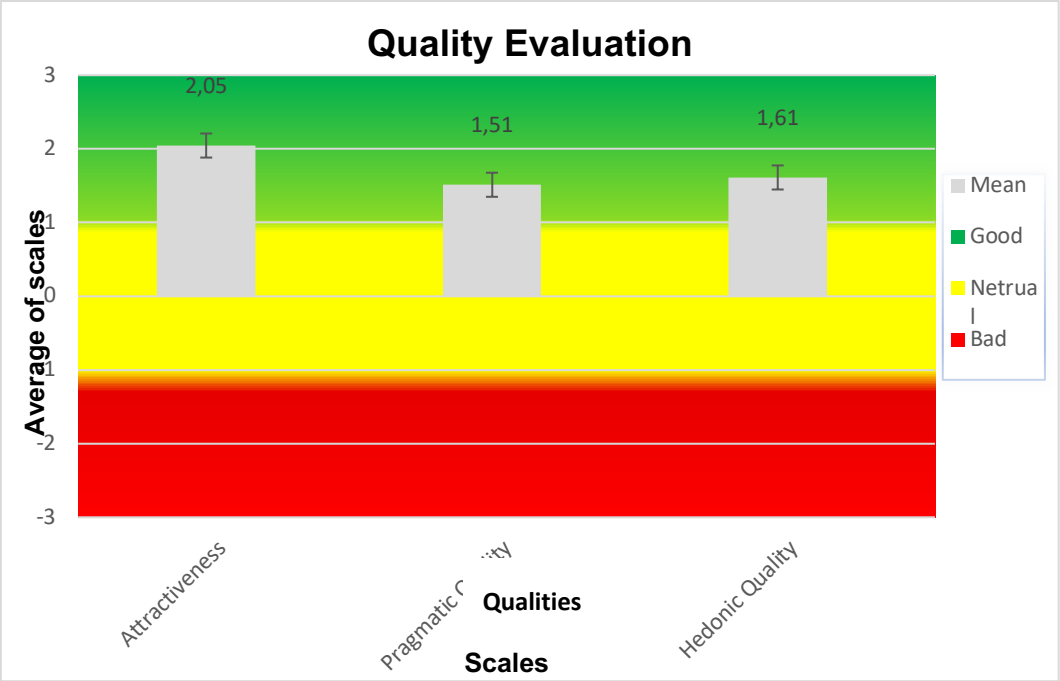

Figure 2. Quality Evaluation

From this figure, we can confirm that the EduCITY app prototype created a positive impression regarding all qualities, where, “Attractivity” (2.05) is the strongest quality in the app, followed by the “Hedonic quality” (1.61). Hedonic quality describes the non-task-related quality aspects, where the “Stimulation” and the “Originality” are the respective scales. On the other hand, “Pragmatic quality” (1.51), where “Perspicuity”, “Efficiency” and “Dependability” are integrated, refers to task-related quality aspects.

Previous studies, related to the EduCITY app prototype evaluation, with data collection from International Doctoral Students in Education [14], applied the same methodology. The results from that study showed that “Attractiveness” (1.43) had also the highest mean evaluation and was also followed by “Hedonic quality” (1.10), then by “Pragmatic quality” (0.90), being modest of all, and so results point that this dimension needs further refinement.

A comparison of the results from the above mentioned previous study [14] with those obtained in the present study, with students of elementary and secondary school levels, allows for the identification of emerging differences. It is anticipated that doctoral students [14] will possess greater knowledge about education proceedings than teenage students, given their higher level of academic graduation. Consequently, their views are likely influenced by their advanced academic education. In contrast, teenage students may be more accustomed to new and emergent technology than doctoral students. Therefore, they may possess greater tech experience, which could serve as a significant influencing factor. However, further research is necessary to obtain more data and accurately infer these differences.

3.2 Benchmark Evaluation

In this sub-section, we discuss the Benchmark evaluation regarding our software (Figure 3) and analyse the relative quality of the EduCITY app prototype when compared to other software products from the Benchmark database. This method compares our results with those obtained regarding other data sets, containing 468 studies with 21175 respondents.

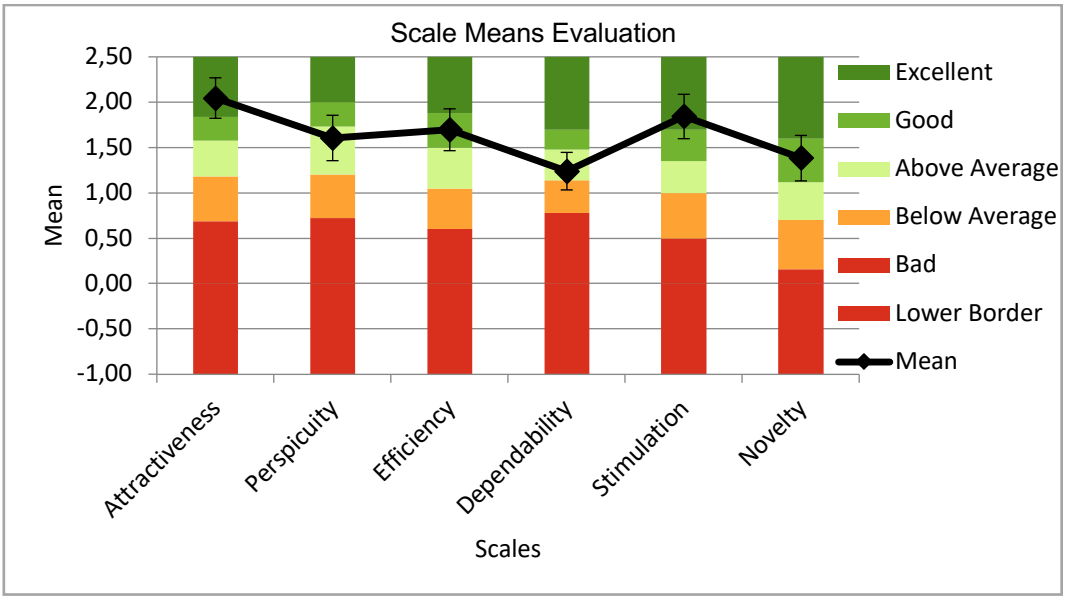

Figure 3: Evaluation of the EduCITY app using the Benchmark database

In this Benchmark analysis, all the quality scales are classified as “Above Average” and “Good”, and in some cases, like “Attractiveness” and “Stimulation”, the “Excellent” is reached, when comparing with other products in the Benchmark database, which gives us a good insight about this app. However, “Dependability” and “Perspicuity” still need to be improved to a higher level, so the respective scale means can achieve “Good” or “Excellent”.

It should be noted that the previous survey study with doctoral students [14] yielded a more reserved evaluation compared to our findings with teenagers. Interestingly, the previous study [14] categorised the EduCITY app prototype’s “Attractiveness”, “Stimulation”, and “Novelty2 as “above average”, while “Perspicuity” and “Efficiency” fell into the “below average” range. “Dependability” was rated as “bad” compared to the benchmark dataset. This suggests a potential influence of the user group (doctoral students vs teenagers) on the perception of the app’s usability.

4 CONCLUSIONS

This study examined the user experience of the EduCITY app prototype among students in grades 7-11 from Aveiro, Portugal. The students (186) participated in an outdoor game activity that integrated Mobile Augmented Reality Games (MARGs), a promising approach for enhancing K-12 learning. The study analysed data collected with the validated User Experience Questionnaire (UEQ) [17]. Valid questionnaire responses corresponded to 44% of the participants (n=82). These participants revealed an overall positive user experience. The EduCITY app prototype's strengths lie in its "Attractiveness" (mean = 2.046, CAC = 0.89), "Stimulation" (mean = 1.842, CAC = 0.89), and "Efficiency" (mean = 1.696, CAC = 0.77). These findings suggest that the app effectively engages students, fosters a stimulating learning environment, and offers an efficient and pleasant user experience. However, the area of "Dependability" (mean = 1.324, CAC = 0.43) requires further development to ensure secure and predictable interactions within the app.

The positive results for "Attractiveness" and "Stimulation" strongly align with the project's objective of using MARGs to promote student engagement in sustainability-focused learning. The app's favourable positioning in the UEQ benchmark evaluation, particularly in "Attractiveness," "Stimulation," "Efficiency," and "Novelty," further reinforces its potential as an engaging and effective educational tool. By leveraging the inherent appeal of games and augmented reality, MARGs like EduCITY have the potential to change learning paradigms. This transformation can convert passive learning into an active and stimulating experience, fostering deeper student engagement with educational content, and resulting in improved knowledge and a more positive attitude towards learning [14]. Furthermore, MARGs show potential in fostering critical thinking, problem-solving, and collaboration – all crucial 21st-century skills for success in today's world.

Future work regarding the app development will focus on enhancing its design and content to address “Predictability” and user expectations. These changes are also expected to positively impact the

“Novelty” scale by introducing fresh ideas and originality. It’s important to acknowledge that perceived efficiency can be influenced by factors beyond the app itself, such as the user device capabilities. While app optimization can improve efficiency, these external limitations should be considered when setting realistic user experience expectations.

While the percentage of valid questionnaire responses (44%) presents a limitation, the analysis of a reliable dataset (CAC > 0.7 for 4 in a total of 6 scales) provides confidence in the results, which are useful in future iterations for improve the EduCITY app. Conducting future studies with larger and more diverse student samples could offer a more comprehensive understanding of the app's user experience across different demographics. Additionally, the use of qualitative research methods, such as interviews or focus groups, could provide a deeper understanding of students' perceptions and experiences when using the app.

This study significantly contributes to the growing body of research on user experience in educational MARGs. It highlights the viability of game-based approaches in promoting sustainable learning and student engagement, which aligns with Goal 4 of the 2030 Agenda for Sustainable Development [18]. The EduCITY team can use these findings to refine the app prototype, with a focus on improving dependability for a more secure and user-friendly experience. Further research could explore the effectiveness of the app in promoting learning outcomes and student attitudes towards sustainability. This would provide a more comprehensive understanding of its impact.

In the future, research could investigate the effectiveness of MARGs in promoting specific learning outcomes across different subject areas. Additionally, it would be beneficial to explore the motivational aspects of MARGs, such as the impact of gamification elements like points, and leaderboards on student engagement and intrinsic motivation. Finally, longitudinal studies could be conducted to track the long-term impact of MARG-based learning on student achievement, sustainability attitudes, and the development of 21st-century skills. By addressing these research questions, it is possible to gain a comprehensive understanding of how MARGs can transform traditional learning paradigms and contribute to a new era of engaging and effective education for all, promoting not only academic success but also a more sustainable future.

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