DESIGN & DEVELOP A SMART LEARNING CITY ENVIRONMENT FOR SUSTAINABILITY

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Abstract

To progress towards the goals of the 2030 Agenda, citizens must have opportunities to develop key competences in sustainability. Mobile devices, augmented reality and outdoor games can be mobilized to promote education for Sustainable Development for diverse target publics. Thus, there is a need of research changes in sustainable development competences in citizens brought about by the exploration of a smart learning city environment, sustained by mobile Augmented Reality (AR) game-based resources. This is a work-in-progress report on a design-based research approach for development of the technological facet of a smart learning city environment for education for sustainable development, under the EduCITY project. It is expected that the EduCITY will produce a technology-enhanced intervention, using a mobile app with AR challenging games, co-created by citizens through an open and easy to use access platform, supporting participatory dynamics. Once the games are created, the citizens can also explore AR games in strategic paths in the city. The games are grounded in city-based aggregating topics, promoting education in context and lifelong learning. It is a challenging and ambitious endeavour, where citizens commit to transformation and engage in it for the benefit of cities' quality of life and sustainability. Nevertheless, several difficulties are foreseen that need to be addressed, such as issues regarding AR triggering and interactivity, and connectivity with environmental sensors. Future work involves several cycles of testing the prototype and, after a functional version, the organization of sessions for game co-creation and, afterwards, the preparation of activities for the community to play the games in the city. These experiences enlarge the creative, multi/interdisciplinary response that seeks to provide situated learning opportunities for all, throughout the creation of participatory dynamics involving the academy and the community. The EduCITY contribution for the knowledge progress is its innovative framework based on a grounded, participatory, and user centred approach for the development of key competences for sustainable development, by using a smart technology and moving Education to a Smart City. This is anchored on a community-based participatory project integrating AR location games based on challenges, to be explored in the city, in formal, non-formal and informal educational contexts, in a socio constructivism approach.

Keywords: Mobile learning, augmented reality, game-based learning, Education for Sustainable Development, design-based research.

1 INTRODUCTION

Education for Sustainable Development must empower learners to take informed decisions and responsible actions. To achieve sustainability an action-oriented transformative pedagogy must be developed, integrating self-directed learning, participation and collaboration under a social constructivism approach, problem-orientation, inter and multidisciplinary approach, linking formal and informal learning [1].

Mobile devices are the most frequent digital technology used for Education for Sustainable Development in outdoor settings with different target groups [2]. The devices can: 1) increase student motivation [3]; 2) be used by students to document learning *in situ* [4], 3) sustain time management and the adequation of the pace of learning [2], among other benefits. Yet, mobile learning approaches can be expensive, due to devices and internet costs, and require technical skills from teachers; thus, these need guidance or professional development initiatives [4]. When combined with **augmented reality** (AR) contents, the educative effect of mobile devices may be exponential [5]. In education, AR has been used to: 1) support the development of high-risk skills, such as piloting [6], 2) allow the visualization of difficult concepts [7], 3) promote personalized learning [8], to name a few. However, in education, AR is usually linked to textbooks and printed material [7], not taking advantage of the potential of mobile devices supported AR to provide contextual and situated learning [5]. The integration of **game-based learning** approaches may enhance engagement in challenging situations and improve student overall

sense of enjoyment, whilst promoting effective learning [9]. Future developments involve creating better learning experiences, supported by the users' experience *in situ* [10].

From the above and from the need of analysing potential changes in sustainable development competences in citizens brought about by the exploration of mobile AR game-based resources, emerged the **EduCITY** (https://educity.web.ua.pt/), a project developed by a multidisciplinary team of University of Aveiro, in Aveiro, Portugal. The project aims to promote sustainability learning through a disruptive smart learning environment, sustained by a mobile app with active location games with diverse educational resources (AR, data from environmental sensors, etc.). For that, EduCITY will produce a technology-enhanced intervention, using a mobile app with AR challenging games, co-created by citizens through an open and easy to use access platform, supporting participatory dynamics. Once the games are created, the citizens can also explore AR games in strategic paths in the city. The games are grounded in city-based aggregating topics, promoting education in context and lifelong learning.

The main purpose of this contribution is to present an approach to develop the technological facet of a smart learning environment towards sustainability learning in a specific city. Hence, the remaining of this work presents the methodological options, where it is shown that EduCITY involves the adoption of a pragmatic paradigm with a design-based research approach [11] towards a technological based solution, through successive cycles of improvement. The following section presents the preliminary results, regarding the smart learning city environment technology, which is under development, and final, some conclusions are put forward. The technology enhanced city learning environment is being developed, but, when ready, it can be replicated in other cities, challenging conventional thinking about how people can learn about their city and change their habits towards sustainable and resilient cities.

2 METHODOLOGICAL OPTIONS

Under a **pragmatic paradigm**, **mixed methods** are being used in a **design-based research** approach, which is a useful framework for developing technology-enhanced learning environments, such as mobile learning delivered by mobile handheld devices [11]–[14]. The design-based research methodology comprises several cycles of improvement of a solution prototype.

In this technology focused study, the aimed solution is a **smart learning city environment towards sustainability** that is currently under development. Initial work includes an analysis and exploration stage [14], to shape a better understanding of the problem. It was conducted through literature review and brainstorming of ideas for the app, AR contents and web platform. This work supported the progress to the second stage, of design and construction [14], with the definition of specifications for a subcontracted programmer, who is producing the first prototype.

Under the evaluation and reflection stage [14], the first prototype will be analyzed by the research team and by the project's expert consultant through heuristics analysis to identify issues regarding usability, AR triggering, connectivity with environmental sensors using Internet of Things technology [15], among others, for improvement. New mature versions of the technological solution are field tested in four improvement cycles involving activities with small groups of students, teachers, and public. Data collection instruments (observation grid and focus group interview guide) are validated by experts and consider ethical aspects and procedures. The resulting data are analyzed through content analysis. The findings are reflected upon to refine the understanding about if, how and why the technology-enhanced solution work. Additionally, after successive evaluative cycles for improvement, it is expected to achieve a functional solution comprising a mobile app, a web-based platform for game creation by non-programmers, and a set of challenging games in the city, integrating AR contents and environmental sensors, ready to be implemented and evaluated with different target publics.

Finally, throughout the entire research process, special attention is given to implementation and spread, in articulation with practitioners, particularly school teachers, in order to study changes in knowledge, skills, values, and attitudes towards sustainability through inquiry (before and after activities), *in situ* observations and game data.

3 PRELIMINARY RESULTS

As mentioned, the EduCITY design-based research started with the analysis and exploration stage [14], where literature recommendations were considered, such as the promotion of personalized learning [8] and the support of the users' experience *in situ* [10]. It also involved several work meetings, of the whole

team and in small groups, to brainstorm and compile ideas for the smart learning city environment. The **main features** intended for the smart learning city environment are:

1) An easy-to-use and freely accessible **mobile app** towards education for sustainability, comprising AR multimedia resources to be integrated in outdoor games developed in different paths and places within the city, such as the university campus, schools and non-formal educational spaces (natural parks, museums, culture houses, and science centres);

2) An easy-to-use open access **web platform**, to allow citizens (educational stakeholders, academy and the wider community) to co-create activities and challenges to be integrated as games in the app;

3) A set of activities to **create AR educational games** with teachers, students, and the wider community. These activities can be accredited training advanced courses for teachers, learning sessions for students, and informal workshops for the wider community. Masters and PhD students are also involved in the creation of location-based games. The games include AR contents, 3D animations, and data from environmental sensors, which are used to create interactive challenges to stimulate participants to detect environmental changes in the city and to identify hidden clues for best game performance and knowledge improvement. Motivation game elements include competition among teams, collaboration within teams, score keeping, and immediate feedback provided by a friendly mascot, who also guides players through learning paths. The games are grounded on aggregating curriculum topics, namely Clean Energy, Food Waste, or Pollution, and city-based topics, as Infrastructures, Services, or Urban Culture;

4) A set of activities to **explore the created games** by students and teachers from Primary up to Higher Education, teacher educators and trainees (articulating the educational offer of the involved departments of the University of Aveiro), and the wider community (inhabitants, tourists and public).

These experiences enlarge the creative, multi/interdisciplinary response that seeks to provide situated learning opportunities for all through the creation of participatory dynamics involving the academy, local government, teachers, children, inhabitants, and city visitors.

Based on the initial literature review and brainstorming, the ideas were co-constructed and negotiated among several project team members, to achieve a solution integrating all the required features. From the work resulted the wireframes of the app and platform.

3.1.1 The mobile app

The mobile app sustains location-based games with challenging activities. The initial screen supports starting a new game, access to the free mode, seeing the score previously achieved, and learning the game rules (how to play), as shown in Figure 1, a).

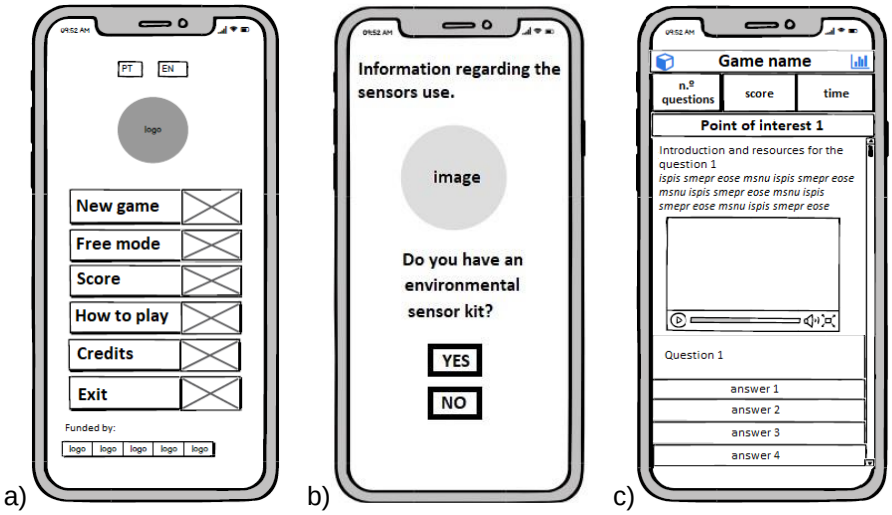

Figure 1. EduCITY mobile app wireframe examples: a) initial screen; b) screen with information regarding the use of environmental sensors; and c) screen with a multiple choice question.

For each game, the user can see information, such as the school level or school subject the game was developed for, number of points of interest or if it includes AR. After selecting a new game, the user must indicate if he/she will be using an environmental sensor provided by the EduCITY team (Figure 1, b). In case of “yes” option selection, the user is prompted to connect the kit and will collect sensor data

regarding: i) particulate and others, ii) NO_2 and others, or iii) noise. That data is collected and aggregated in graphs in ThingSpeak (https://thingspeak.com/), and made available in the EduCITY website (https://educity.web.ua.pt/), for the community to have access.

The AR experiences are possible through 2D markers, such as architectonical tiles or trees identification plaques. Other types of AR triggering will be studied under EduCITY as well.

Following, the user starts playing. He/she will be "accompanied" by a friendly Flamingo mascot to find points of interest in the city, where he/she will be prompt to observe, to have access to information in multimedia format, including AR, and to answer multiple choice questions (Figure 1, c). After selecting an answer option, differentiated feedback is shown. At the end, the user will have access to the achieved score, number of questions answered correctly, time of play, etc.

3.1.2 The web platform

The games are created by non-programmers, in a web platform (Figure 2). Each user must create an account to be able to use it. With this tool the user can define written information, such as the initial message of the game, and multimedia resources, such as specific digital content used to create AR experiences, to include in phase of the game. For each point of interest in the city, defined by the user, he/she: i) introduces information regarding how to find its location and why it is interesting, and ii) creates multiple choice question(s), including the answer options and feedback to provide to the players accordingly to game performance. The number of answer options can vary from two to four, and the correct options can also vary in this range.

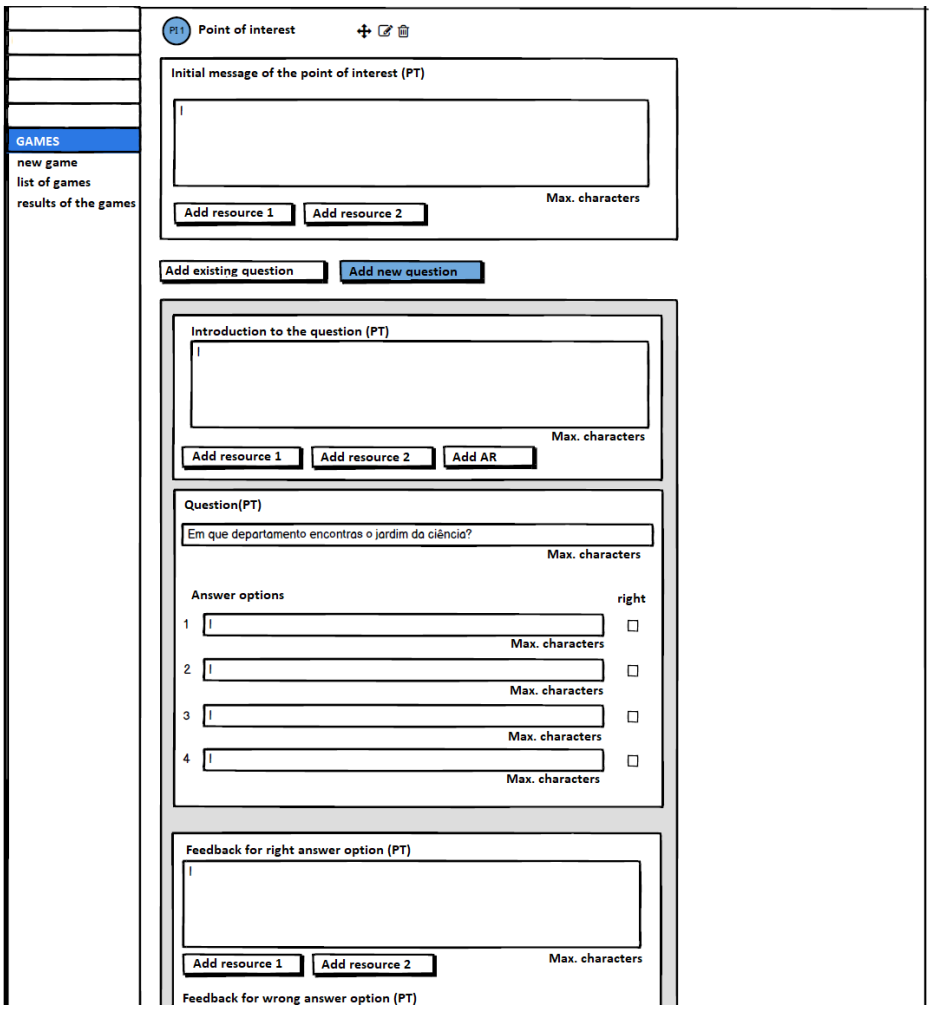

Figure 2. EduCITY web platform wireframe example: question creation.

Multimedia resources can be included to contextualize the players, to give information, to support the visualization of difficult concepts, among other aims. For that, a content repository (video, audio, 3D models, …) is integrated in the platform, which is fed by the research team and by the platform users.

Both the AR markers and the digital content for AR experiences are created by the EduCITY team. They can, however, be also created by users (Figure 3), for greater flexibility and project sustainability after the funding period. The users can create three types of AR experiences, such as associating a 3D object to a marker, subtitling an image or creating a button screen with information.

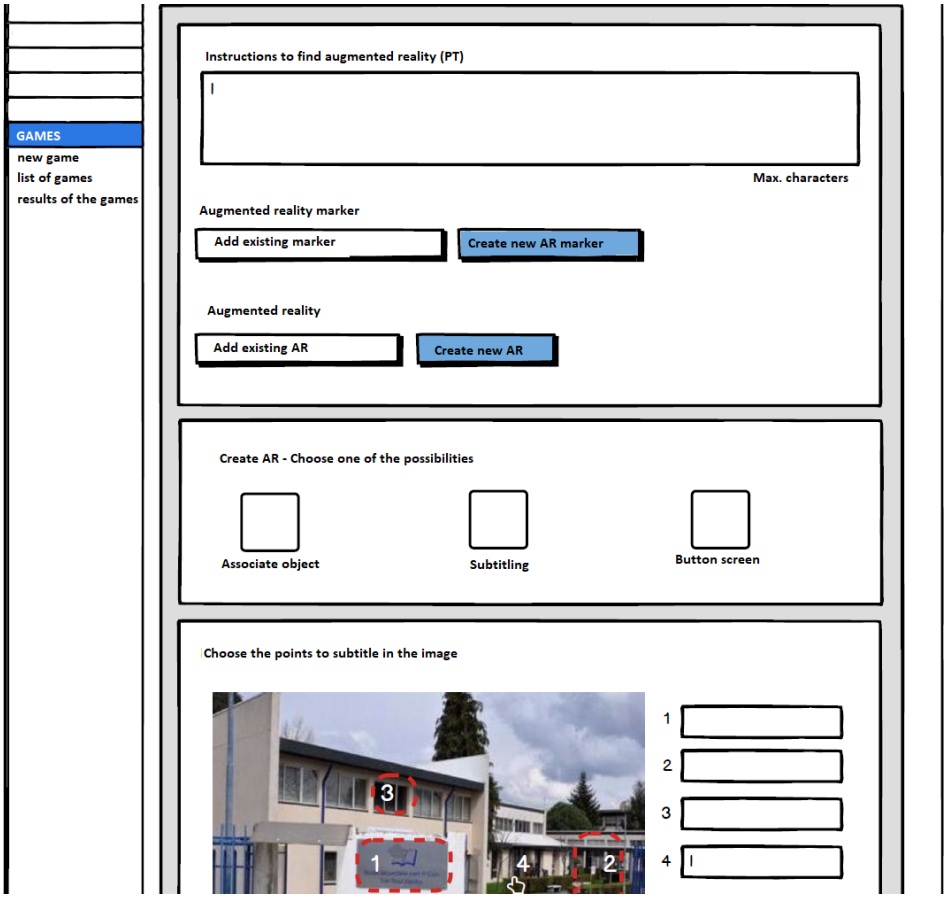

Figure 3. EduCITY web platform wireframe example: AR creation.

Participatory dynamics are supported by the platform. Each user can invite other authors to co-create content and games, by introducing one or more email addresses in the platform. The invitees receive an email with information and direct link to the platform. They must create an account or login into the platform to accept the invitation.

Games are always available for their creators to use in the app, through the use of a code. To be publicly available, games can be submitted to validation by members of the research team. The platform collects anonymous game logs for the game creators to be able to analyse and decide on eventual improvements to conduct.

4 CONCLUSIONS

This work-in-progress study present an approach to develop a smart learning city environment towards changes in citizens' sustainable development competences. It is expected that the EduCITY will produce a technology-enhanced intervention, using a mobile app with AR challenging games, co-created by citizens through an open and easy to use access platform supporting participatory dynamics. With this tool, citizens will also be able to explore AR games in strategic paths in the city. The games will be grounded in city-based aggregating topics, promoting education in context and lifelong learning.

The EduCITY innovation lies in: a) the use of the territory as a living experimental laboratory, moving Education to a real-life context; b) the use of widely-used smart technology with AR mobile games; c) community participation, giving opportunities for all to actively contribute, in a social constructivism approach; d) wide knowledge sharing between the university and the community; e) the applicability of this approach to any city to build a digital, green and healthy future for everyone. The development of a

technology that can support such innovative smart learning city environment is a challenging and ambitious endeavour. Here, citizens are asked to commit and engage in the transformation of their city towards sustainability, for the benefit of cities' increased quality of life. In such a challenging proposal, several difficulties are foreseen, as issues regarding AR triggering and interactivity, and connectivity with environmental sensors. These must be addressed during the design-based research, in order to achieve a mature, easy-to-use and fully functional solution.

Considering the characteristics of the adopted methodological option, future work involves several cycles of analysing and testing the prototype and, after a functional and mature technological version, the organization of activities for game co-creation by the community, particularly educational stakeholders, as students and teachers. Afterwards, the games created through participatory dynamics need to be tested and explored *in situ*, so the project also organizes activities for the community to play them in the city. These experiences enlarge the creative, multi/interdisciplinary response that seeks to provide situated learning opportunities for all through the creation of participatory dynamics involving the academy and the community.

The design-based research does not only provide the design, implementation and evaluation of an intervention in practice [14]. This methodology is characterized by its dual outputs: one is the intervention and the other is a deepened theoretical understanding of phenomena associated with it, such as success factors and constraints. More specifically, the EduCITY contribution for the knowledge progress is, precisely, its innovative framework. As mentioned above, the framework is based on a grounded, participatory, and user-centred approach aiming the development of key competencies for sustainable development, by diverse citizen stakeholders. These sustainability competences development is supported by smart technology accessible to everyone in modern societies, such as mobile devices and AR, which allows moving Education from the classroom to a Smart City. This is anchored on a community-based participatory project integrating AR location games based on challenges, to be explored in the city, in formal, non-formal and informal educational contexts, in a social constructivism approach.

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