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APPLYING USER-CENTERED DESIGN FOR A CLIMATE RESILIENCE VIDEO GAME

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ABSTRACT: Serious games for education have the potential to raise awareness among the general public and to increase professional knowledge in emerging domains such as climate resilience. Climate resilience is a new topic both for professionals and in the terms of life-long learning. In this context, the process of design and developing educational video games, has to apply a user-centered design approach and take into consideration the user experience metrics to significantly improve its educational and motivational outcomes. The paper aims to outline the main stages for the design and implementation of an educational video maze game in the field of protection of monumental cultural heritage. The video game "Let's save Venice" is part of the learning resources of the EU-funded project e-Creha. The paper introduces the context of the game development and, next, outlines the main steps and findings for its design and evaluation. Finally, it presents some results of the game validation and user evaluation.

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1. INTRODUCTION

Serious educational games have the potential to raise general public awareness and increase expert knowledge [1], especially in emerging domains such as climate change and climate resilience. It appears that educational resources, and particularly the serious video games dedicated to topics of climate change, climate resilience, and protection of the built heritage, are rare. At the same time, an increasing number of professionals from multidisciplinary fields such as urban planning, engineering, architecture, city administration, and others, as well as citizens and building owners, need to be better prepared to cope with the increasing challenges imposed by climate change.

Being a partner in the project e-Creha (https://www.ecreha.org/), the team from Sofia University is responsible for the design and development of educational video maze games dedicated to climate change. As found in the project, architectural education has paid very little attention to the vulnerability of the built heritage to climate change and has overlooked the contribution of heritage to the development of climate-adaptive strategies for a resilient society. Raising awareness among the general public is significant as cultural heritage contributes to social cohesion, sustainable development, and psychological well-being. Thus, protecting heritage means promoting resilience.

Stepping on the APOGEE platform for the design of educational video maze games [2], the Sofia University team designed, implemented, and validated the educational video game "Let's save Venice". By outlining the user-centered approach, the work aims to reflect on the main stages for the design and implementation of educational video maze games. The paper is structured as follows. The first part makes a short overview of the main concepts of User-centered design in serious maze video games for learning. The second part discusses the steps for the game "Let's save Venice" design and development. Last, the validation context is described, along with a summary of the results.

2. USER-CENTERED DESIGN IN EDUCATIONAL MAZE VIDEO GAMES

The main focus of the adopted user-centered approach is to improve the User experience (UX), taking into consideration different factors, determining the quality of interaction between the users and the systems, focusing on its effectiveness and efficiency, and adding criteria like attractiveness, aesthetics, or joy-of-use [3]. Based upon the previous research of [2], we applied a user-centered design approach and created the educational

video game "Let's Save Venice." The design of this educational video game aims to cover all important aspects of UX for serious games, combining factors such as playability, learnability, and usability. The key elements for UX in (serious) educational video games are reflected: e.g., factors such as gaming experience, learning experience, usability [4, 5], engagement, emotional and cognitive elements (inner emotional level); game content (goals of the game and learnability aspects); fun and flow factors [6, 7], challenge, playability, usability learnability, efficiency, memorability, errors, and satisfaction [8].

Based on the review in [2], the following main factors for UX in games are selected grouped in three general facets: playability, learnability, and usability.

Playability – consists of a group of factors such as Gaming experience, Challenge (the perceptions of the game difficulty by players), Immersion, Game flow, Affect (confidence, self-efficacy, and attitudes), and Motivation to engage [9]. Fidelity in a serious game can be associated with the level of realism that the environment provides to the user. Presentation of in-game graphics and audio affects player immersion and engagement.

Learnability – often, the learning experience is associated with educational game effectiveness, the setting of clear goals, and available feedback to provide a learning opportunity [2]. The game content should be aligned to the educational objectives and curriculum within which it is embedded. Content appropriateness and integration refer to the game activity, promotion reflection on the knowledge and skills that the game provides to players. Further, they maintain encouraging the integration of knowledge from different areas to support player's decision-making and developing new knowledge from the game. Media matching within serious games is used to identify the most appropriate media to use, such as animation, sound, picture, or text within a game.

Usability – the UX characteristics of usability cover factors such as ease of use of the interface, user control within the gaming environment, the avoidance of errors, and satisfaction with the game's interactive features [10]. Usability explains how the user can achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use. The components of usability are the following: (1) effectiveness – the accuracy and completeness with which customers players achieve specified goals (measured in completion rates and errors); (2) efficiency – the accuracy and completeness of goals achieved concerning player effort and resources (e.g., time on task and number of trials); (3) satisfaction – the positive attitudes and experience from the use of the system.

3. RESEARCH METHODOLOGY

Before proposing a game design, the initial stage covered short research on available educational resources, learning games, educational projects, and publications in the field of climate change, climate resilience, building cultural heritage, and monumental cultural heritage protection. The Sofia University (SU) team performed a desktop study of existing online video games, covering Climate changes or/and Built heritage. The team found a total of 37 video games, considering several aspects such as the game type, dimension (2D or 3D), game genre, and online resources. The search process was conducted in the period February-March 2021 by using the most popular search engines (Google, Bing, and Baidu), together with Web of Science and Scopus. The exploration of games is performed according to the different combinations of the following keywords: game(s), mini-game(s), puzzle(s), climate, climate change, environment, environment protection, heritage, built heritage, cultural heritage, monuments, sustainability, resilience, vulnerability in the languages of the partner countries (English, Spanish, Italian, and Bulgarian). The search queries have also returned several descriptions of games matching keywords, though the games were unavailable because they were Flash-based or their host sites were expired or inaccessible.

For each digital game, the team collected detailed information, e.g., about objective, brief description core game loop, mechanics, dynamics, aesthetics of the game. Based on these data, several significant conclusions are made. The predominant genres appeared to be puzzles and action-adventure games. Nearly half of these games are dedicated to monumental cultural heritage (actually, 15 games plus a collection of 28 games and mini-games about ancient Rome), while 21 video games are about climate change. On the one hand, 27 games are about resilience, 18 – about impact, 5 – about vulnerability, and 13 – about adaptation. On the other hand, 28 of all the games are single-player games, whereas only 9 games are multiplayer video games. The majority of the games (26) are 2D games, while the other ten games appeared to have a 3D graphic interface and one – 2.5D.

It has to be highlighted that many commercial entertainment games explore historical monuments, architectural sites, and cultural heritage buildings though, they can hardly be used as serious games for teaching and learning purposes. Raising awareness and increasing the popularity of historical monuments and buildings, these games can attract the attention of young students on the protection of cultural heritage. However, different discussions among history teachers reveal that popular entertainment games often mix real facts with fiction, use not-verified sources, and thus are not suitable for

educational activities.

4. GAME IMPLEMENTATION

The prototype of the game "Let's save Venice" is developed within the project e-Creha. It is designed by using the serious game development platform APOGEE [11] for only three months. It is created by XML description of the enriched maze that includes different types of didactic mini-games. Using this XML description in the Unity 3D editor, a 3D maze is generated [12]. The game can also be personalized and adapted in the manner described in previous publications of the authors [13, 14]. The game "Let's save Venice" is an educational video game representing a five-hall maze with information tables and different built-in mini-games (puzzles and quizzes) corresponding to the educational game scenario.

Learning objectives are aimed at exploring how built heritage is vulnerable to extreme weather and hazards and how these issues can be addressed. Further, the goals are to experience the resilience strategies to protect built heritage toward climate change. These objectives are achieved through different types of puzzle mini-games that provide didactic tasks dedicated to enhancing the player's skills and knowledge. Playing goals and rules require the players to pass through all the maze halls by unlocking doors for the next rooms. For this purpose, students have to answer a question concerning the didactic content placed on the learning boards in each hall. Before answering the door-unlocking question, the players should play and solve all the puzzle mini-games in the respective room.

The design of the educational 3D video game-maze embraces the following steps:

1. Setting learning objectives and creating a game scenario reflecting them;
2. Collection and selection of relevant textual and multimedia content;
3. Modeling of appropriate types of didactic mini-games;
4. Design of audiovisual layout of the maze halls;
5. Generation of online versions of the game;
6. Testing and validation of the initial version of the game with target users.

Figure 1 presents the maze map that consists of the following rooms: Introduction, The Context, The Problem, The Solution, and The Future. All the maze halls present

educational content corresponding to their name. The player's mission in the video maze game is to understand how Venice can be saved from ever-growing floods by getting acquainted with the multimedia materials on the information boards. Then, using the acquired knowledge to solve the built-in learning tasks (different types of mini-games). The process of learning and playing should take a minimum time with maximum efficiency. To achieve the mission goals, the player must pass through all the maze halls, complete all mandatory game tasks, and find all hidden objects, thus collecting the maximum number of points (i.e., achieve the maximal result).

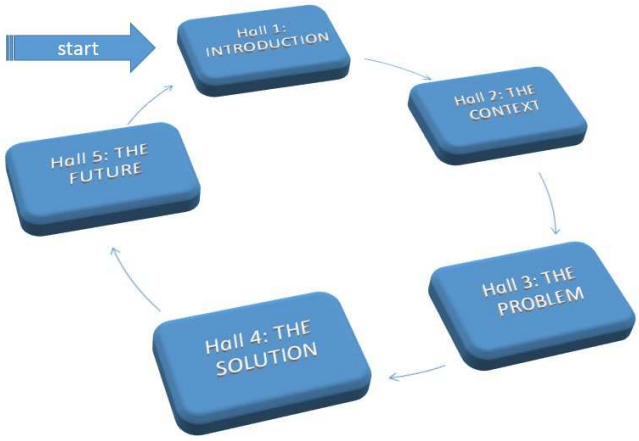

Figure 1. The maze map of the game "Let's save Venice"

The game "Let's save Venice" aims to explore the main factors, problems, and solutions for climate resilience and the protection of monumental cultural heritage in Venice. Currently, the mini-games built into the maze halls are the following five types [15]:

1. Rolling balls marked with text or a picture to the corresponding positions or rings on the floor map in the hall (Figure 2, bottom right);

2. Detection of hidden (translucent) objects to obtain points;

3. Finding hidden words in a table with ordered letters by marking a sequence of letters (Figure 2, bottom left);

4. Finding hidden pairs of tiles (two identical words/ images, or word and the corresponding image) by clicking on them (Figure 2, top right);

5. Arranging images according to a given attribute by placing them in the corresponding positions (Figure 2, top left).

Figure 2. Screenshots from the game "Let's save Venice"

5. GAME VALIDATION AND DISCUSSION

The final stage of game development includes testing and validation of the initial version of the game "Let's save Venice". It was performed during the e-Creha project workshop held from 31 of August to 8 of September 2021 in Technical University at Eindhoven, the Netherlands. The workshop aims at implementing and testing new pedagogies according to the specific themes of the modules. Totally 24 students from the target audience – students in architecture, urban design, and cultural heritage domains, both from Bachelor and Master Programs participated in the testing process. Initially, the students were introduced to the game, its learning and playing goals, and rules by a presentation and discussion. The playing time was planned to be 15–30 minutes, though some students played for up to an hour. After the playing session, the students were asked to fill in an online survey aimed at exploring their opinions about the learnability, playability, and other characteristics of the maze game.

Based on the preliminary results, some of the main UX factors were identified and measured both for the educational maze game and the mini-games. Figure 3 presents reported mean values of these factors (Flow, Challenge, Competence, Positive and Negative affect, Immersion, and Tension) for two mini-games – the matching pictures

game and the game of rolling balls to positions or rings. The evaluation range covers the Likert five-scale range, corresponding to five levels of presence for each one of the seven factors, namely 5 – very high, 4 – high, 3 – medium, 2 – low, 1 – very low. The outcomes prove that UX factors Flow, Competence, Immersion, and Positive affect are reported with relatively high mean values (greater than 3.5 excepting Challenge), while the Negative affect and Tension are presented with low levels.

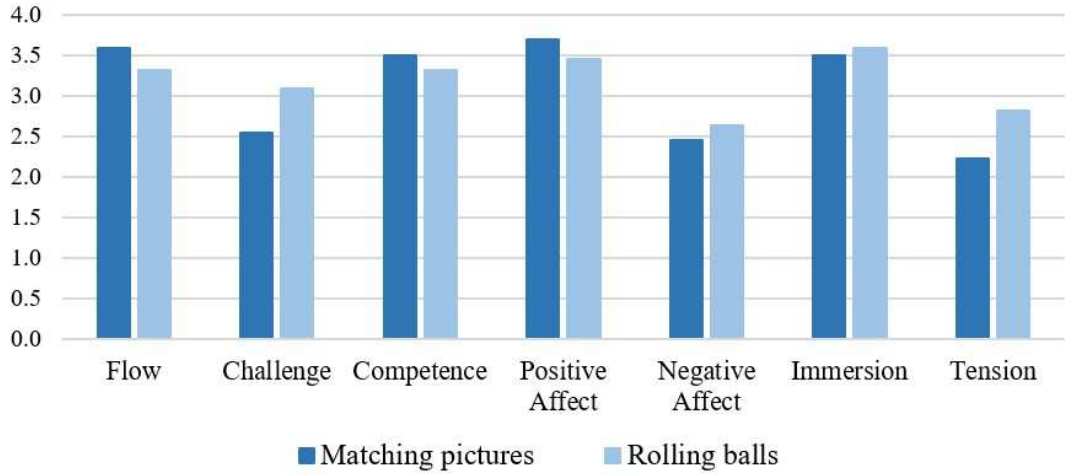

Figure 3. Comparison of the user experience factors for two mini-games

6. CONCLUSION

The user-centered approach to creating educational video games focuses on both the design and development of such games to the needs and essential modeling characteristics of the final game players, i.e., the learners. The paper presented a study in the educational video games area where the user-centered approach was applied to the design and development of a 3D maze game dedicated to climate resilience of monumental built cultural and historical heritage in the context of saving Venice from ever-growing floods. The conducted practical experiment for game validation proved that the importance factors of user experience such as Flow, Challenge, Competence, Positive and Negative affect, Immersion, and Tension are reported with considerably good levels. Thus, game validation has proven the benefits of the user-centered approach to creating games for learning.

Further research activities will be focused on developing a similar maze game dedicated to the climate resilience of built cultural and historical heritage and its vulnerability. The e-Creha project plans the creation of three more maze games. The authors

of the paper hope these maze games will provide even better learnability, playability, and user experience. They will contain enhanced mini-games, adaptive gameplay [16] and, as well, virtual players helping the individual learners by answering their questions and reading the texts presented on the learning boards in each one of the maze halls.

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