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Virtual Reality Escape Rooms for STEM Education in Industry 4.0: Greek Teachers Perspectives

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***Abstract*—Science, Technology, Engineering and Mathematics (STEM) skills comprise a crucial meta-discipline for success in the 21st century. Education in the industry 4.0 era can be enhanced by adopting Virtual (VR), Mixed (MR), and Augmented (AR). VR can support creative student-centered teaching and learning methods in STEM, such as playful learning, gameful learning (gamification), and serious games. Serious escape rooms are digital interactive, live adventure breakout games with a pedagogical rationale. This paper examines the perceptions of K-12 school education teachers towards digital educational escape rooms for STEM education in VR environments. Twenty-eight Greek teachers responded to a questionnaire after having experienced a cost-effective science-themed digital escape room. Results indicate that teachers reacted positively to the VR escape room, appreciating its value for learning. Moreover, they are eager to engage in professional development activities and embrace gameful learning methods.**

Keywords—Virtual Reality; STEM; digital escape rooms; escape rooms; e-learning; distance education; serious games;

I. INTRODUCTION

The convergence of fast-evolving technologies such as cloud computing, high-speed broadband cellular networks, robotics, artificial intelligence, internet of things, nanotechnology, immersive technologies, 3d printing, big data, and machine learning has marked the transition in the industry 4.0 era. These exponential technologies enable the emergence of autonomous smart manufacturing processes and installations [1]. This profound radical shift impacts employment and the economy as it is expected to lead to a novel work distribution between humans, machines, and algorithms. Repetitive, automated labor routines and roles will be redundant while new jobs and roles will be required for the newly developed services. Industry estimations expect a positive global impact on employment, predicting a strong demand for new jobs [2].

As a result, new generations of learners and teachers in school, vocational and higher education need to be equipped with appropriate skills and competencies. Meanwhile, the existing workforce will need to undergo mass-scale reskilling and upskilling in the frame of life-long learning [3]. Education in the Industry 4.0 era can be enhanced with the wide adoption of immersive technologies in the Extended Reality or Cross Reality (XR) spectrum; Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality [4], [5]. These technologies can enhance and supplement both formal education [6] and on the job training with wearable devices [7]. For instance, VR can set up virtual learning factories where learners can be immersed in challenging concepts and experience authentic cases [8]. AR can provide feedback in additive manufacturing to improve human-machine interaction [9]. Furthermore, VR and AR can support a variety of active and creative student-centered teaching and learning methods such as playful learning, gameful learning (gamification), and serious games [10]–[12]. In this direction, teachers' perceptions are critical for accepting, exploring, and integrating these methods and technologies into their mainstream teaching practice [13].

This paper aims to examine and present the perceptions of Greek K-12 school education teachers towards the serious games-based teaching approach of digital educational escape rooms for STEM education implemented in virtual reality environments.

II. BACKGROUND

A. STEM Education

What essential skills do students need to thrive in the 21st century Industry 4.0 era? Science, Technology, Engineering and Mathematics (STEM) are educational areas that have been identified internationally as crucial for the economy and society [14]. Despite high levels of unemployment in several

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regions, there is a lingering shortage of STEM skills [15]. This is reflected in national and international policies such as the European Skills Agenda. The European Skills Agenda is a five-year policy project aiming at supporting individuals and businesses develop new and improved competencies [16]. One of the agenda's twelve key actions is the increase of STEM graduates and transversal skills ensuring that people will have proper skills to access the job market.

B. Virtual Reality

Virtual Reality enables mental transportation into another context, a computer-generated environment fully separated from the actual user's surroundings [17]. VR can support several instruction models and contemporary learning theories for student-centered teaching and learn in STEM fields [18]. For instance, immersive VR mediated by a head-mounted display could significantly improve learners' self-efficacy in STEM subjects [19]. VR can help students experience what it is like to be a STEM professional and towards these careers [20]. Social VR platforms support flexible distance education and training [21] and remote communities of inquiry and practice [22].

C. Digital Educational Escape Rooms

Play and game design are increasingly associated with education and work as educators, and stakeholders strive to improve performance and affective outcomes [23]. VR environments are excellent for adding game elements in the educational practice due to their affordances and personalization capabilities. Game-based approaches include project-based, inquiry-based, and problem-based learning [24]. Commonly used mechanics for gameful interventions in VR include a story, realism, role-play, collaboration, movement, status, points, competition, token, levels, and the game turns [25].

Escape rooms are interactive, live adventure breakout games in one or more physical spaces (rooms) where players collect clues and solve puzzles to complete a mission, usually to exit one or more rooms [26]. Serious escape rooms are digital escape rooms with a pedagogical purpose [26]. They can be classified as a serious game form in digital, 3D virtual environments. Escape rooms are constructed around a theme (e.g., space or mystery) and a narrative where users are called upon to fulfill their mission. Learning attributes should be purposefully aligned with game mechanics to facilitate the attainment of the intended learning objectives [27]. Educational escape rooms have been used effectively in STEM education both in physical and digital environments [28].

III. METHODS & MATERIALS

This study intended to examine the perceptions of school teachers towards digital educational escape rooms in Virtual Reality. More specifically, the teachers' experience after playing a science-themed serious e-scape room was evaluated. The experienced digital escape room was titled "Room of Keys" on the role of enzymes, a topic in the subject of Biology, translated into Greek (Fig. 1, 2). The escape room has produced positive effects in adolescent US learners [29]. The particular breakout room was selected for this study because teachers developed it without any external professional support. It was hosted online in a cost-effective way using a cloud computing service and playing it did not require the installation of any program or plugin.

Fig. 1. Aerial snapshot of the starting scene in the breakout room

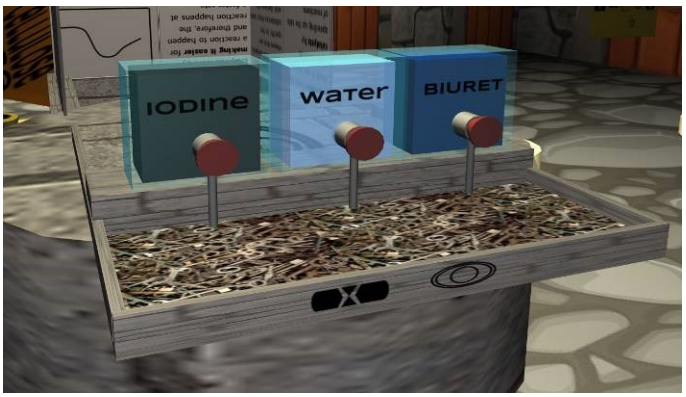

Fig. 2. Escape room challenge (puzzle) with hints as symbols pointing to theory

The main research instrument used was a 30-item questionnaire to measure the teachers' enjoyment, learning benefits, motivation, and satisfaction from a validated survey instrument [30]. The items were translated into Greek by the first author and were approved by two experts who examined the quality and accuracy of the translation. Most items were formulated as a statement of positive or negative connotation. Participants were prompted to mark their degree of agreement by selecting a value in a five-level Likert scale ranging from entirely disagree to absolutely agree. Additionally, observation and unstructured feedback through chat and an open question in the questionnaire were secondary data collection mechanisms.

Participants in this pilot study were twenty-eight school teachers serving in primary (elementary) and secondary education in Greece. 64,3% of participants were female, 46,4% in the age group 45-54 years old, while 50% was distributed equally between the 35-44 and 55+ age groups. 35,7% served in high schools, 28,6% in middle schools and 25% in elementary schools. The 33,3% taught natural sciences, 29,6% technological or engineering subjects, while 25,9% taught humanities or language courses. Regarding their experience

with VR, 64,3% identified themselves as novices or beginners and selected values 1-3 of a 7-level Likert scale). Only 25% expressed high familiarity with VR (values 5-7 in a 7-level Likert scale).

The questionnaire was anonymous and was administered electronically in June 2021. Participants were selected by convenience, as they joined an online event (webinar) about the application of virtual worlds in education. The used escape room was hosted online, and registered participants received the link to play it voluntarily and then answer the questionnaire if they choose to. Participants could visit and play the escape room at their leisure without any external help, instruction, educational resource, or support.

IV. Results & Discussion

A. Questionnaire Evaluation

As a result of the heterogeneity of the participants and the absence of external supports, only 64,3% were able to complete the escape room. This diversity is also reflected in the total time spent (Fig. 3) and the estimated difficulty level of the puzzle activities illustrated in (Fig. 4). 32% found the puzzle activities to be slightly very or too difficult, while another 32% characterized them as slightly, very, or too easy. Furthermore, more than 1 in 4 participants (28,6%) reported that they encountered some difficulty while playing the escape room (Fig. 5). These difficulties were mainly problems with movement or camera angle (view) in the 3D environment. They were not related to the platform's performance or stability. It is worth mentioning that users were teleported first in an area surrounded by a tutorial with technical and strategic instructions on how to navigate and exit the environment. However, this was not enough to safeguard a smooth experience for all.

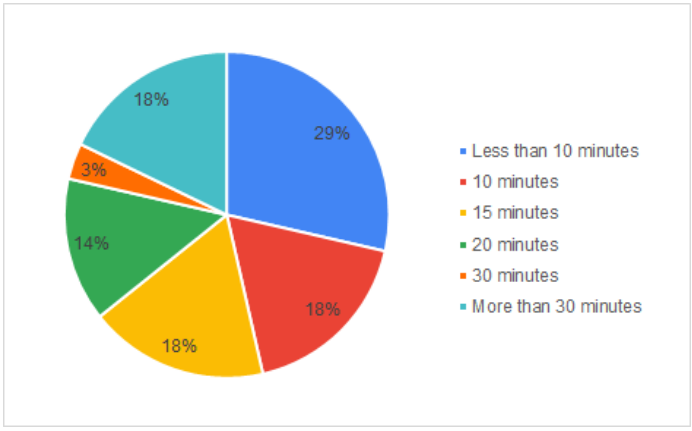

Fig. 3. Engagement with the serious escape room (time spent).

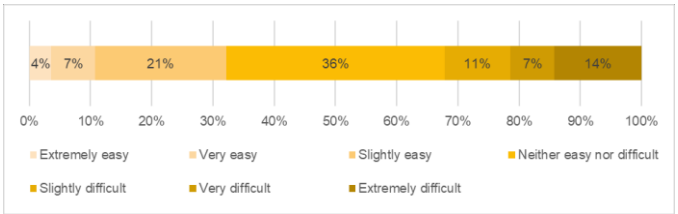

Fig. 4. Perceived difficulty level of escape room puzzles

The participants' perception towards VR and computer simulations is quite positive as they find them pleasant (89,3%) and enjoyable (78,1%). The played escape room captured their attention (78,6%) and was not boring (71,4%), so most of them (57,4%) thought it was quite enjoyable. Teachers found the digital educational escape room beneficial for learning as it facilitated mainly the retention (67,8%), comprehension (78,5%), and application of knowledge (64,3%). Hence, the experienced learning activities were assessed as meaningful for learning (82,1%). In terms of satisfaction, teachers approved the included teaching methods (64,2%) and the learning effectiveness (60,7%), leading to an overall 64,2% appreciation of the serious escape room experience.

B. Open Feedback

Some teachers expressed their desire to have access fully translated into the local language in their open feedback. Although all content, signs, and audio were in Greek, some interface elements remained in English. Others stressed the need for more detailed instructions at the beginning and instant personalized feedback to advance in the game and not feel stuck. Indeed a few teachers faced technical challenges and were not able to complete the game. These comments confirmed the importance of having a tutor in the role of a facilitator, a game-master who intervenes with hints and tips whenever necessary to ensure a friction-less experience. Moreover, teachers have the vital task of leading debriefing sessions after the escape room has been played to discuss the experience, assess the outcomes towards detecting and consolidating lessons learned. This indicates that digital escape rooms are more suitable for synchronous learning.

Several teachers also expressed their eagerness to embrace gameful learning methods and engage in professional development activities in VR. More specifically, they initiated spontaneous chat discussions to inquire about the possibility of creating their escape rooms either through self-study and experimentation or participating in continuous professional development programs.

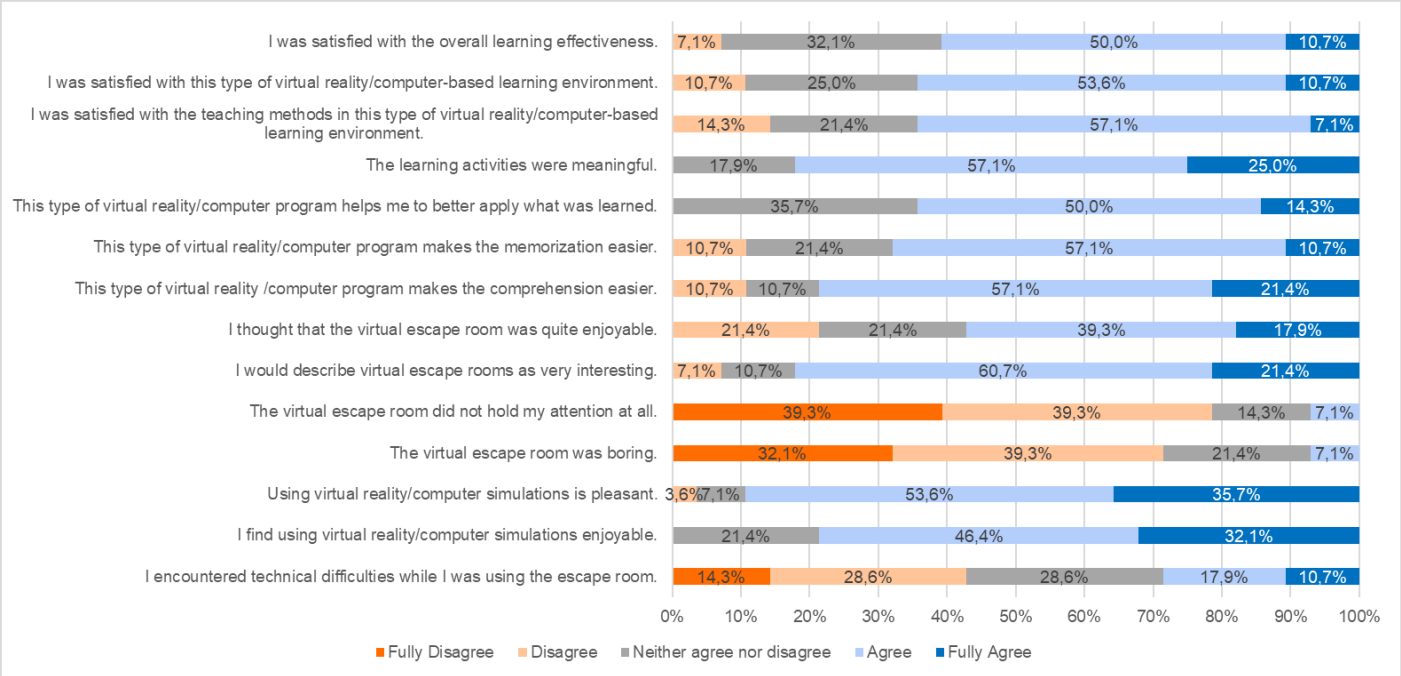

Fig. 5. Satisfaction, Learning benefits, enjoyment

V. Conclusion

In this study, the perceptions of Greek school teachers regarding the educational use of a VR escape room were examined. As this was a limited sample, it cannot be considered representative of the total population. However, the fact that the sample included teachers from all subjects and that a strong majority had very little exposure and experience with VR were factors that could alleviate potentially biased, techno-optimist opinions. The overall findings indicate that Greek school teachers are ready and willing to adopt innovative methods and technologies that will allow them to move from emergency remote teaching to more profound, significant learning [21], especially in the context of social distancing due to the covid pandemic. The scarcity but also the of promising results of pilot teacher professional development projects [31] should encourage education leaders and policymakers to accelerate systematic professional development actions that will unleash teachers' creativity benefiting learning quality, student motivation, and engagement with STEM to thrive in Industry 4.0 era. Future work should consider the application of escape rooms in other formal educational settings to compare effects and efforts to make escape room design and development accessible to teachers through professional development, physical and virtual communities of practice.

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