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Teacher Perceptions on Virtual Reality Escape Rooms for STEM Education

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Abstract: Science, technology, engineering, and mathematics (STEM) is a meta-discipline employing active, problem-centric approaches such as game-based learning. STEM competencies are an essential part of the educational response to the transformations caused by the fourth industrial revolution, spearheaded by the convergence of multiple exponential technologies. Teachers' attitude is a critical success factor for any technology-enhanced learning innovation. This study explored in-service teachers' views on the use of a digital educational escape room in virtual reality. Forty-one (n = 41) K-12 educators participated in a mixed research study involving a validated survey questionnaire instrument and an online debriefing session in the context of a teacher training program. The key findings revealed that such alternative instructional solutions can potentially enhance the cognitive benefits and learning outcomes, but further highlighted the shortcomings that instructional designers should consider while integrating them in contexts different than the intended. In line with this effort, more systematic professional development actions are recommended to encourage the development of additional teacher-led interventions.

Keywords: virtual reality; escape room; STEM education; online learning; e-learning; distance education; serious games; biology

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1. Introduction

Currently, there is a rapid development of a series of emerging exponential technologies such as cloud and edge computing, high-speed mobile internet, big data, artificial intelligence, robotics, nanotechnology, internet of things, biotechnology, 3D printing, and extended reality [1]. The term exponential points to their continuously and meteorically accelerated pace of innovation. When multiple exponential technologies are unified, they significantly influence, cross-pollinate, and expand their respective capabilities and further accelerate their speed of evolution. As a result, the dominant paradigm of industrial production and manufacturing is expected to change and trigger further socio-economic effects. This radical transformation is labeled as the fourth industrial revolution, leading to the Industry 4.0 era [2]. The previous three revolutions were triggered by the mainstream application of new technologies in industry, namely steam engines, electricity, and computing, respectively, and were connected to major changes in education [2].

Industry 4.0 requires proportional educational responses to accommodate the unfolding requirements and subsequent societal changes. 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 [3]. Repetitive, automated labor routines and roles will be redundant, while new jobs and roles will be required for the nascent services. Industry estimations expect a positive global impact on employment, predicting a strong demand for new jobs [4]. As a result, new generations of learners and teachers in school, vocational, and higher education need to be equipped with appropriate skills and competencies, among others in science, technology, engineering, and mathematics fields. Meanwhile, the existing workforce will need to undergo mass-scale reskilling and upskilling in the frame of life-long learning [5].

Educators' acceptance and willingness to use new technology or new pedagogical methods and media in education is not self-evident. Antunes et al. [6] identified four core types of academic faculty perceptions towards major pedagogical shifts in teaching, namely: (i) active innovation, (ii) passive, theoretical acceptance, (iii) skepticism, and (iv) resistance. Teachers are resistant to technology integration into education if they feel the introduction of new media or methods threatens their role or exacerbates their working conditions [7]. Therefore, educators' positive attitude is a critical success factor for any technology-enhanced learning innovation. Teachers' perceptions depend on the flexibility of the proposed medium, as well as on its usability, ease of use, and perceived cognitive benefits through teachers' access to experiential professional development actions [7–9]. In this context, the study's main aim is the exploration of K-12 educators' views on the use of an educational, virtual reality-based, escape room (VRER) as an educational resource for blended learning in the post-pandemic era. The current study is an extended version of a published conference paper that contained preliminary research results [3].

2. Theoretical Background

2.1. STEM Education

Science, technology, engineering, and mathematics (STEM) are key priorities in education, as competences in these areas are essential and in rising global demand in the economy and society [10]. STEM is more than the sum of its separate field parts. It comprises a meta-discipline that merges the aforementioned subjects into cross-disciplinary curricula to confront authentic, complex, and practical challenges [11]. This problem-centric approach can enhance students' higher-order cognitive skills (e.g., analytical and critical thinking), as well as transversal soft skills such as creativity, ingenuity, communication, and collaboration [12,13]. Effective STEM education relies on active learning activities with a constructivist background. Social constructivism posits that learning is constructed through active engagement and social interaction for personal development [14]. Essential active instructional approaches include project-, problem-, inquiry-, and game-based learning [15,16].

Game-based learning methods in STEM disciplines include playful design, gameful design (gamification), simulations, and serious games [17–19]. Playful design is the application of a curiosity-driven disposition based on humor, imagination, spontaneity, creativity, experimentation, and joy [20]. Gamification involves turning the sum or key aspects of an educational procedure into a structured game with rules and goals based on specific game dynamics and mechanics [21]. Serious games are games with a primary educational, epistemic purpose [22]. They constitute a complex system offering a series of meaningful choices towards a desirable outcome. Serious games provide an epistemic frame for playful socially valued practices that lead to the transfer of competences in authentic contexts [23].

2.2. Digital Educational Escape Rooms

One emergent popular serious game format is the educational escape room or edu-escape room [24]. Escape rooms are popular, interactive, group, live-adventure experiences in physical spaces [25]. In an escape room, players are confined in one or more spaces with a mission, usually to break out of the room. To accomplish their mission, players have to collect clues, perform tasks, and solve polymorphic puzzles, often under time pressure. Although escape rooms constitute entertainment activities, during playtime, users are required to apply multiple analytical, thinking, problem-solving, communication, and cooperation skills. As a result, serious escape rooms have been used in all levels of formal, adult, professional and corporate education for multiple educational purposes and intended outcomes [26]. Notably, the escape room format was conceived from Japan and was inspired by point-and-click first person flash digital adventure video games such as the crimson room and the viridian room [27]. In a sense, it can be argued that digital educational escape rooms are, indeed, returning to their roots.

Designing a digital escape room involves taking into account the following dimensions [28,29]: (i) detecting and analyzing the characteristics and needs of the players; (ii) formulating learning objectives in the cognitive, emotional, social, and psycho-motor domains; (iii) selecting an appropriate theme to inspire and dictate a common aesthetic feeling, language, and atmosphere; (iv) designing the characters and the story underlying the escape room, as well as the narrative during play; (v) designing activities and tasks, hints, evidence, and puzzles aligned with learning objectives; (vi) selecting, developing, and programming appropriate components and props (e.g., non-player characters); and (vii) debriefing and reflective sessions after gameplay to evaluate all aspects of the experience.

Digital educational escape rooms have been implemented mainly in 2D, web-based environments, and are considered an appropriate tool to promote deeper subject comprehension in online distance learning [26]. Escape rooms in STEM disciplines are predominantly structured around the application of clinical and procedural skills in simulated contexts [30].

2.3. Virtual Reality

Immersive, spatial technologies, namely the Metaverse and extended reality, are among the driving forces of the fourth industrial revolution [31]. Extended or cross reality is a hypernym for several technologies such as virtual, augmented, and mixed reality. Virtual reality (VR) involves entering an entirely new, computer-generated digital world [32]. VR is of special interest for education as it facilitates the teleportation of conscience, which immerses users into synthetic spaces where experienced memories, achieved competences, and behavioral change are transferable to the physical world [32,33]. Multiuser VR environments and virtual worlds are enabling the application of various learning forms based on games [34]. Commonly used mechanics for gameful interventions in VR include narrative, visual realism, role-play, collaboration, movement, status, points, competition, token, levels and game turns [34]. Several of these mechanics are essential for escape rooms.

Despite the fact that desktop and immersive VR are being studied from multiple perspectives, there is a scarcity of empirical studies on VRER in STEM (education) fields [35]. While VR has been used as a part or short activity in physical escape rooms, e.g., [36], only two studies with VRERs have been identified in chemistry. Such effort is the study that Elford and colleagues [37] described, which included a VR/AR spy-themed escape room. In this experience, the students were recruited to enter an intelligence agency by deciphering encrypted time-sensitive stereochemistry-based puzzles. Janonis et al. took a step further and organized realistic experiments in an immersive VR environment. Students had to perform chemical experiments accurately to acquire the code to break out of the laboratory [38].

3. Materials and Methods

3.1. Materials

The present study focuses on the perceptions of in-service K-12 educators toward VRER. In order to account for the diverse perceptions and experiences that educationalists from different disciplines have, we invited participants from all of the related scientific fields that participated in an annual teacher training program. Those who accepted our invitation were requested to play a science-themed serious VRER, which is branded under the name “Room of Keys”. The integrated experience is streamlined toward the subject of biology with a genuine focus on enzymes. In line with the main theme of the experience, the keys constitute a linguistic metaphor of enzymes, which act as catalysts in different chemical reactions. Despite the theme-oriented nature of the learning experience, no previous subject knowledge was required as all the key information were provided within the virtual context.

The VRER features three phases: (a) the gameplay tutorial, (b) the presentation of the information, and (c) the knowledge application (Figure 1). In the first phase, the players receive an orientation to the environment, which allows them to develop familiarity with the key functions of the VR space (e.g., mobility and interaction with digital objects), as recommended by [39]. This is achieved through audio instructions and text signs. In the next phase, users collect flying keys (encoded) that unlock content once inserted into the keyholes with the corresponding codes. Five content nuggets are presented in auditory narration and persistent short posters with illustrations and text. The final phase is the most crucial for learning, as players are prompted to apply knowledge about enzymes in four puzzles organized in subsequent levels. The first puzzle is revealed as soon as all content is displayed.

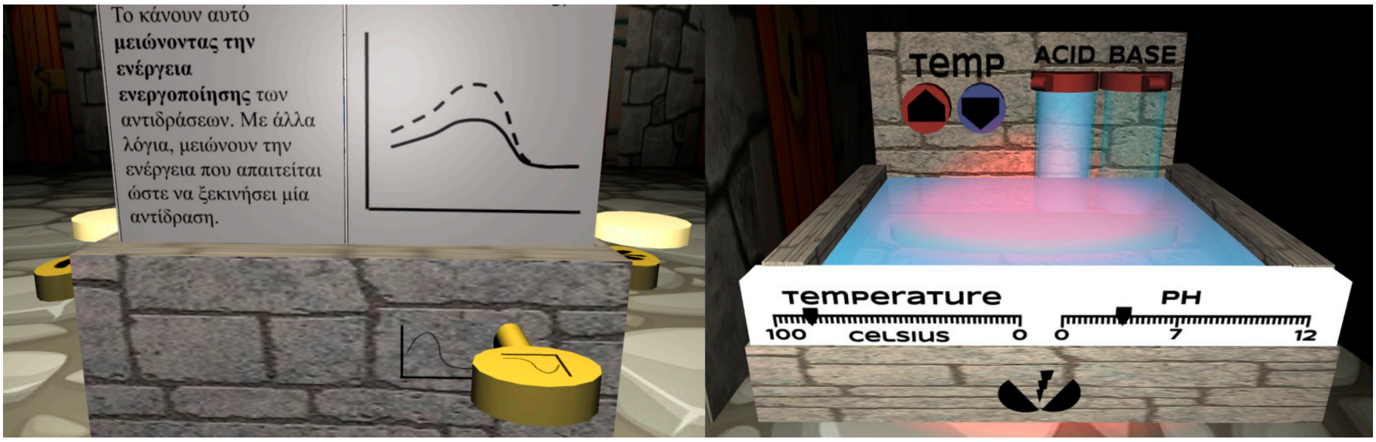

Figure 1. Snapshots of the virtual reality escape room; presentation of information in Greek regarding the function of the enzymes: "enzymes work by making it easier for a reaction to happen and therefore, the reaction happens at a faster rate. They do this by lowering the activation energy of the reaction, or how much energy it takes to get the reaction going". (**left**) Knowledge application puzzle on enzyme denaturing by maintaining an optimal temperature and pH (**right**).

The VRER was initially tested and evaluated by 148 high school students in the USA [40]. Students concurred that VRER is appropriate as an educational resource and self-evaluation activity. Despite the fact that the subject of enzymes was already taught, students recorded an average of 13.8% increase in academic performance. A subsequent experimental study in Finland presented the learning effects of escape room play for biology conceptual knowledge in comparison to a machinima video [35].

The particular breakout room was selected for this study because it was designed and constructed by educators without additional professional intervention. Specifically, it was developed completely online, using the cloud computing platform Amazon Sumerian, without the support of any other third-party software or plugin (e.g., game engine). For the development of such experiences, no programming background is required, thus making it feasible for the average educator to develop device-agnostic and mobile-device friendly educational applications [40]. It was hosted online in a cost-effective way and playing it did not require the installation of any software or plugin on behalf of the users. Therefore, it can be regarded as a scalable, teacher-produced, open educational resource.

3.2. Methods

For the evaluation of the experience, a psychometric instrument was adopted from pertinent literature [41,42] (Appendix A). Additional questions were introduced regarding participants' demographics and overall experience, including prior experience with VR/3D virtual environments, whether they were able to complete the VRER, the total time spent to complete it, whether they faced any technical difficulties, and an estimation of the difficulty level that the escape room puzzles presented. The items were translated into Greek by the first author and were checked by two researchers who evaluated the validity of the translation and its language clarity. Most items were formulated as a statement of positive or negative connotation. After engaging with the VR experience, participants recorded their opinions and thoughts on multiple Likert scale statements. Secondary data collection mechanisms included open-ended questions and informal discussions during the online debriefing session.

The questionnaire was anonymous and was distributed online in June 2021 and January 2022 to individuals who attended two iterations of an online training program about internet safety, online learning, social VR, and gamification in education (convenience sampling). The training program was organized in the Science and Technology Museum of the University of Patras. It aimed at the development of pedagogical, content and technological competencies towards educational innovation. After communicating the concept of VRER, interested participants received a link to play it voluntarily. Participants could visit and play the escape room at their discretion without any external help, instruction, educational resource, or support. Following the completion of the experience, an additional link to the evaluation survey was distributed to the enrolled participants.

The debriefing session took place online, one week later, as part of the scheduled regular group meeting. During the debriefing session, teachers were invited to comment freely on their VRER experience and elaborate further on their questionnaire replies. One of the facilitators posed guiding questions and encouraged an open dialog among the group. This process was based on the principles of the "good interview practices", which include active listening, avoiding confrontations or interruptions, and following up on the main points raised [43].

4. Results

The processing of the primary data was performed using the programming language *R*. The statistical analysis consisted of two-stages: (a) exploration of the data using descriptive statistics (distributions, frequency tables, averages, and standard deviations) and (b) exploration of possible correlations between the dependent and the independent variables to determine any qualitative differences between the sample population. It should be noted that, for the correlation analysis, the adoption of nonparametric statistical tests (Spearman's correlation and Mann–Whitney *U*) was deemed more appropriate due to the limited sample size.

4.1. Demographics

The sample (n = 41) consisted of primary and secondary education teachers emerging mainly from the Western region of Greece (Table 1). The gender distribution was quite asymmetrical, with the females being considerably more than the males. Nevertheless, this is a fairly representative picture of the Greek education landscape and even more so justifiable after considering that most participants are primary school teachers. Although the age period that defines age groups is somewhat arbitrary, the sample can be considered as middle-aged, an observation that is also in line with the current structure of the aforementioned education system. In either case, participants' scientific background demonstrates a fairly equal distribution, which adequately covers all the major fields.

4.2. Evaluation of the Experience

The majority of the participants had no or relatively little experience with VR applications (Figure 2). However, most of them managed to "break out" from the VRER, in a reasonable amount of time, without encountering particular cognitive difficulties (Figure 3), although several mentioned that they encountered technical difficulties (Table 2).

Table 1. Participants' demographic information.

Category		*n*	Percent
Sex	Male	12	29.30
	Female	29	70.70
	Prefer not to answer	0	0.00
Age group	18–34	2	4.90
	35–44	10	24.40
	45–54	20	48.80
	55+	9	22.00
Occupational service level	Primary education	19	46.34
	Lower secondary education	8	19.50
	Upper secondary education	14	34.14
Scientific field	Humanities	13	31.70
	Natural sciences	10	24.40
	Engineering and technology	11	26.80
	Sociology	1	2.40
	Other	6	14.60

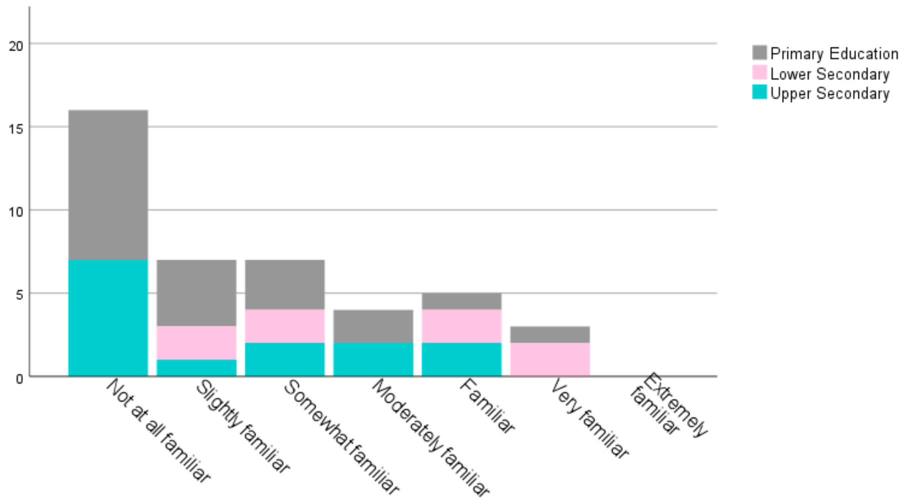

Figure 2. Participants' familiarity with immersive technologies across the different occupational levels.

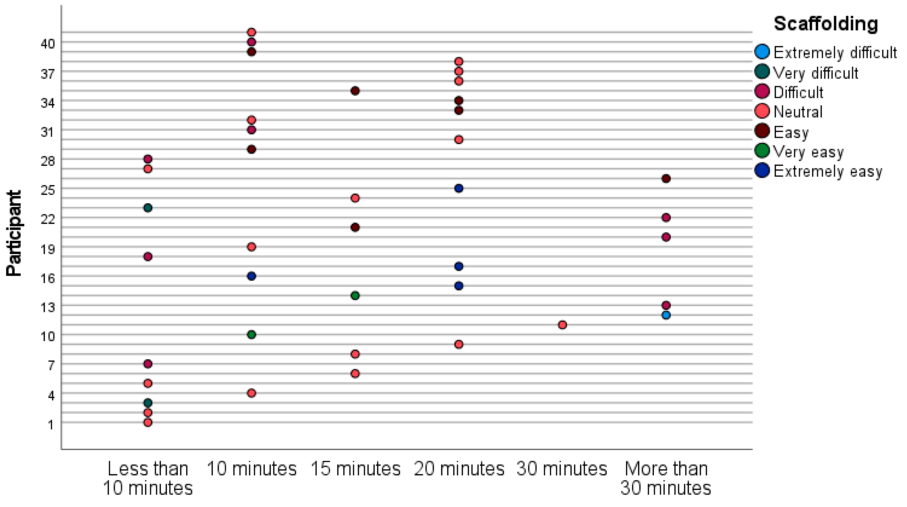

Figure 3. Perceived difficulty of the VRER layers correlated with the time required to complete the experience.

Table 2. Multifactor assessment of the virtual reality escape room experience.

Category	Response	*n*	Percent
Familiarity with VR	Extremely familiar	0	0.00
	Very familiar	3	7.30
	Familiar	5	12.20
	Moderately familiar	4	9.80
	Somewhat familiar	7	17.10
	Slightly familiar	7	17.10
	Not at all familiar	15	36.60
VR Escape Room completion	Yes	25	61.00
	No	16	39.00
VR Escape Room completion time	Less than 10 min	8	19.50
	10 min	10	24.40
	15 min	7	17.10
	20 min	10	24.40
	30 min	1	2.40
	More than 30 min	5	12.20
Scaffolding of difficulty per stage	Extremely easy	4	9.80
	Very easy	2	4.90
	Easy	7	17.10
	Neutral	16	39.00
	Difficult	9	22.00
	Very difficult	2	4.90
	Extremely difficult	1	2.40
Experienced Difficulties	Fully agree	8	26.80
	Agree	10	29.30
	Neither agree nor disagree	12	24.40
	Disagree	11	19.50
	Fully disagree	0	0.00

The main themes of concern, as elaborated in the open-ended questions and in the debriefing sessions, regarded the lack of detailed instructions on the steps required to engage with the problem-solving tasks or the absence of procedural information with regard to the progression to the subsequent stages. To facilitate the reader's understanding, we provided some indicative quotes:

Participant A: "More detailed instructions or support to proceed when stuck".

Participant B: "I did not manage to break out through the escape room. Neither did I truly understood what I had to do. Having more information about the procedural steps would have been really helpful".

In the specific VRER, user movement was implemented by a point-and-click mechanism in several specified places in VRER. This information was mentioned both in the initial oral pre-recorded instructions and in the informational panels, however not all participants were able to interpret this information correctly and act accordingly.

The aforementioned claims were also backed up even after considering the positive feedback we received:

Participant C: "I managed to escape the room and found it overly interesting as a game. However, it should be noted that I am a Mathematician with a Master's degree in Computer Science!!".

Reference was also made to the language barrier, as some aspects of the activities were in English (i.e., differed from the participants' mother language).

Participant D: "The instructions should have been in Greek. If we are to consider transferring these activities in the classroom context, with school students who have no prior-experience with such tools, the language barrier will be a serious issue".

Notwithstanding the foregoing, for some educators, the overall experience was utterly satisfying and enjoyable:

> Participant E: "Very interesting material! Congratulations to the creators!".
>
> Participant F: "The 3D environment, the flying keys, as well as the white ladder created by the individual pieces (in combination with the music) were impressive! The graphics are of very good quality and can be compared to the standards that modern computer games have in terms of immersion and user experience".

Teachers appreciated the fact that they did not have to install anything and could enter the VRER in seconds. In the debriefing session, more experienced peers recommended increasing the sophistication of the game. Suggestions included the creation of a hint system that would allow users to activate clues explaining what to do next should they get stuck. The team agreed that this would be very useful in VRERs of a longer duration that were intended to be played without instructors being present.

They stressed further the importance of being able to experiment and even fail purposefully in some activities, as students often do so as to test the system. Learning by trial and error and repeated engagement was seen as a reinforcing factor of deeper comprehension [44]. Several of them expressed interest in designing and building their own educational escape rooms. More specifically, they asked to be trained on how to build digital escape rooms based on specific puzzle design categories and templates. As a result, additional professional development sessions were scheduled on the topics of gamification, escape room design, and digital escape room creation.

The reliability coefficient (Cronbach's alpha) of participants' responses to the psychometric survey ranged from 0.83 to 0.95 (Table 3). According to [45], the proposed satisfactory level was 0.70, which, subsequently, allowed us to argue that the ratings given to the examined statements had a high reliability.

Table 3. Descriptive statistics for the user experience questionnaire constructs.

Construct	Min	Max	M	Med	Std. Dev.	Cronbach's a
(C1) Perceived enjoyment	2	5	4.18	4	0.76	0.92
(C2) Motivation	1	5	3.29	4	1.29	0.93
(C3) Cognitive benefits	2	5	3.75	4	0.74	0.83
(C4) Learning effectiveness	1	5	3.72	4	0.84	0.93
(C5) Satisfaction	1	5	3.48	4	0.96	0.95

The first construct (C1) examined the degree of enjoyment that participants felt when engaging in activities that involved the use of VR simulations. The majority of educators maintained an overly positive attitude across the given statements, an outcome that could be attributed to the playful and ludic nature that such virtual environments inherently had. The second construct (C2) examined the various forms of motivation that were linked to the interest individuals had in completing the VRER challenge. The technical difficulties as well as the relatively high failure rate (approx. 40%) to complete the experience, significantly influenced the responses provided to these statements, which can be overly described as "neutral". The third (C3) construct examined participants' views with regard to the cognitive benefits that the undertaken experience can offer whereas, the fourth construct (C4), focused on the learning effectiveness of this alternative instructional approach. Educators maintained an equally positive attitude across both constructs, which allowed us to conclude that they identified both the added-value and the educational potential of the integrated method. The final construct (C5) gauged the degree of satisfaction that participants felt during their engagement with VRER. Motivation and satisfaction are considered to be highly interconnected behavioral traits that determine individuals' interest to engage with a process and persistence to attain the desired goals or outcomes, respectively. The responses (ratings) in these statements were fairly in line with the ones provided in C1 (motivation), which, collectively, confirmed that the challenges and the difficulties that participants faced greatly affected their experience. Finally, in consideration of recent research works that have explored the role that gender plays on multimedia technology adoption for learning [46,47], we hypothesized that the gender difference may have a noticeable effect in the present study, too. However, no significant correlations could be identified across the explored dimensions (Tables 4 and 5). Although this outcome could be justified after considering the small sample size as well as the imbalanced distribution of the sample (gender-wise), it can still offer insight on the potential of this alternative instructional approach to benefit individuals regardless of their gender.

Table 4. Correlations between participants' gender, prior experience, and performance in the VRER experience.

Dependent Variable	Independent Variable	Spearman's *rho*	*p*
Familiarity with VR	Gender	0.016	0.921
Escape Room completion		0.171	0.280
Completion time		−0.096	0.547
Experienced difficulties		0.079	0.621
Scaffolding of challenges		−0.118	0.457

Table 5. Correlations between participants' gender and the present experience.

Dependent Variable	Grouping Variable	*U*	*Z*	*p*
Perceived enjoyment	Gender	147	−0.804	0.422
Motivation		150.5	−0.681	0.496
Cognitive benefits		169.5	−0.132	0.895
Perceived learning		123.5	−1.457	0.145
Satisfaction		123.5	−1.460	0.144

5. Discussion

Often in education, changes and new media are introduced using the top-down approach, where a technological solution is selected or developed at the national, regional, or district level and is offered to educators. In contrast, a bottom-up approach involves the educators' activation and collective action within a emergent community of practice [48]. Such strategies place high trust on educators and rely on their inherent interest to produce useful open and customizable materials through peer collaboration and review processes. This constructivist grassroots approach can be further expanded to propel students into the role of content producers. In this case, digital artifacts become evidence of knowledge mastery through coordinated transdisciplinary group project work. This practice in the context of game-based learning is well-known as modding, where players modify aspects of the game system and create their own game levels [49,50]. This constitutes a new, proposed direction of research.

According to [51], escape rooms have the potential to reinforce individuals' competencies in problem solving, while also facilitating the shift from rote (memorization) to problem-based learning. In this work, while building on the notion of physical escape rooms, we explored and discussed the educational potential of a low-cost alternative instructional method that aims at stimulating users' creativity and analytical thinking. The knowledge acquisition, the development of understanding, and the elaboration of the relevant concepts was achieved through a series of consecutive puzzles and problems that promoted the use and development of important cognitive skills.

Teachers with higher-order technical knowledge, skills, and competencies valued the importance of integrating and utilizing such innovative solutions in the teaching-and-learning practices considerably more. On the other hand, educators with limited technological competencies found it hard to engage and interact with the VR experience. Furthermore, the absence of formal training on the subject under investigation (Biology), as well as the fact that parts of the VR experience were delivered in a language other than the native language, constituted the key barriers that greatly impacted the overall experience and satisfaction. This outcome was also in agreement with the study that was conducted with regard to the integration of intelligent tutoring systems in contexts that differ from the intended one [52]. However, the variable "gender" did not seem to have any significant impact on participants' performance or attitude toward this approach.

In either case, the key contribution of the present work goes beyond the exploration of the pedagogical potential of the demonstrated VRER as it also aims to pave the pathway for the wider adoption of such solutions in streamlined teacher professional training programs.

6. Conclusions

In this work, the attitudes of K-12 educators regarding the pedagogical usefulness of VRER were analyzed. The study used a convenience sample, hence findings cannot be generalized and applicable to the total population. However, the fact that the sample included teachers from all subjects and genders, a strong majority of whom had little exposure and experience with VR, were factors that could alleviate potentially biased, techno-optimist opinions. The overall findings indicate that a sample of Greek school teachers are ready and willing to adopt innovative methods and technologies that will allow them to apply active and student-centered blended learning scenarios in the post-pandemic era. The scarcity but also the promising results of teacher professional development projects should encourage education leaders and policymakers to accelerate systematic professional development actions that will unleash teachers' communities of practice and creativity benefiting learning quality, student motivation, and engagement with STEM to thrive in the Industry 4.0 era.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Questionnaire items regarding participants' perceptions.

Item	Description	Source
C1	**Perceived Enjoyment**	
1	I find using virtual reality/computer simulations enjoyable.	[41]
2	Using virtual reality/computer simulations is pleasant.	
3	I have fun using virtual reality/computer simulations.	
C2	**Motivation**	
4	I enjoy working with the virtual escape room very much.	[42]
5	Virtual escape room activities are fun to do.	
6(R) *	The virtual escape room was boring.	
7(R)	The virtual escape room did not hold my attention at all.	
8	I would describe virtual escape rooms as very interesting.	
9	I thought that the virtual escape room was quite enjoyable.	
10	While I was doing the virtual escape room I was thinking about how much I enjoyed it.	

Table A1. *Cont.*

Item	Description	Source
C3	**Cognitive Benefits**	
11	This type of virtual reality/computer program makes the comprehension easier.	
12	This type of virtual reality/computer program makes the memorization easier.	[42]
13	This type of virtual reality/computer program helps me to better apply what was learned.	
14	This type of virtual reality/computer program helps me to better analyze the problems.	
C4	**Perceived Learning**	
15	I was more interested to learn the topics.	
16	I learned a lot of factual information in the topics.	
17	I gained a good understanding of the basic concepts of the enzymes.	
18	I learned to identify the main and important issues of the topics.	[42]
19	I was interested and stimulated to learn more.	
20	I was able to summarize and concluded what I learned.	
21	The learning activities were meaningful.	
22	I can apply what I learned in real context.	
C5	**Satisfaction**	
23	I was satisfied with this type of virtual reality/computer-based learning experience.	
24	A wide variety of learning materials was provided in this type of virtual reality/computer-based learning environment.	
25(R)	I don't think this type of virtual reality/computer-based learning environment would benefit my learning achievement.	[42]
26	I was satisfied with the immediate information gained in this type of virtual reality/computer-based learning environment.	
27	I was satisfied with the teaching methods in this type of virtual reality/computer-based learning environment.	
28	I was satisfied with this type of virtual reality/computer-based learning environment.	
29	I was satisfied with the overall learning effectiveness.	

* (R) = reversely coded item.

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