Virtual Museum Gamification for Discovery-Based Online Learning in the Metaverse

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Keywords: Metaverse, Virtual Reality, Social Virtual Reality, Webxr, Gamification, Playful Learning, Informal Learning, Online Learning, Museum Education, History Education, Science Museum.

Abstract: During the pandemic, museums were forced to deploy innovative methods and platforms to serve their audiences, especially schools. Immersive technologies, such as social virtual reality environments in the Metaverse, can enable the creation of online virtual museum exhibitions. Indifferent or tiresome educational procedures can be transformed into appealing, enjoyable experiences with gamification. In this pilot exploratory study, the perceptions of elementary education teachers on the gamified online exhibition "Out of love for Greece" in the Metaverse are investigated. A qualitative research design is employed involving interviews, observations, and post-test scores. Findings indicate that WebXR technology met the expectations of participants, especially for asynchronous individual and group self-study. Gamification mechanics enhanced the motivation of less-interested pupils and increased their interest and engagement with digital content. This study provides useful insights and suggestions for the design of effective playful learning experiences in the Metaverse.

1 INTRODUCTION

Museums and science centres aim to become education excellence destinations where visitors and, especially children and school pupils, can observe scientific phenomena in practice and learn informally by experience. Beyond visiting the museum spaces and collections, students can participate in engaging training programmes, interact with exhibits, become curious, aware and interested in facets of human cultural and scientific heritage.

The COVID-19 pandemic disrupted all classroom-based education activities involving physical mobility (Kostas et al., 2023). While emergency remote teaching was implemented out of necessity in all levels of education, museums could not resort easily to this method, as their exhibits and programmes are usually of participative nature based on active learning. Hence, new innovative methods had to be deployed in science museums to reach and serve their regular audiences.

In response to these unprecedented disruptions, the present study introduces and preliminary assesses an innovative gamification method for informal online learning within digital museum exhibitions in the Metaverse. Specifically, it presents the design, development and evaluation of the temporary Metaverse exhibition "Out of love for Greece". The manuscript concludes by offering insights into the potential of gamified learning environments to enrich and transform the educational landscape especially in view of the Metaverse and its impact in distance education.

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Mystakidis, S., Theologi-Gouti, P., Christopoulos, A. and Stylios, C.
Virtual Museum Gamification for Discovery-Based Online Learning in the Metaverse.
DOI: 10.5220/0012756600003693

In *Proceedings of the 16th International Conference on Computer Supported Education (CSEDU 2024) - Volume 1*, pages 711-719
ISBN: 978-989-758-697-2; ISSN: 2184-5026

2 BACKGROUND

2.1 Immersive Technologies in Museum Education

Immersive technologies include Virtual Reality (VR), Augmented Reality (AR) and the Metaverse. Virtual Reality allows the creation of synthetic, digital, computer-generated spaces that can be used for learning purposes in education. AR overlays digital information in the physical environment that can be accessed via mobile and wearable devices (Koutromanos et al., 2015). Museums have used immersive technologies mostly to engage learners and visitors and offer informal learning experiences (Fokides & Atsikpasi, 2018; Ng et al., 2018). Museums have employed collaborative virtual environments or virtual worlds to host virtual events (Mikropoulos & Natsis, 2011; Vosinakis & Tsakonas, 2016). Moreover, immersive technologies can be used to increase the accessibility to museum exhibition; an action of mass communication with a meaning making purpose (Lester, 2006).

Thanks to VR and the Metaverse, the concept of a virtual museum, a museum without walls (Schweibenz, 2019), has been extended to provide virtual experiences that would be impossible in the physical world. Digital exhibitions in VR enable roaming in ancient cities, traveling across space to the Mars surface and inhabiting art-inspired immersive spaces (Shehade & Stylianou-Lambert, 2020). Notable studies in the history and heritage fields include the Picts & Pixels exhibition (Cassidy et al., 2018) and an immersive experience around the Antikythera mechanism, the first analog computer of the world (Chrysanthakopoulou et al., 2021). VR can be instrumental in visualizing objects and structures of historical significance that do no longer exist in the physical environment (Morsman et al., 2022). However, as VR efforts in museums were based on stand-alone immersive VR systems providing single-user experiences, the lack of social interaction was identified as the primary limitation and challenge (Shehade & Stylianou-Lambert, 2020). This gap can be addressed with virtual museum exhibitions in the Metaverse, an open and persistent multiuser environment merging physical reality with digital virtuality (Mystakidis et al., 2024).

2.2 Gamification

Playful attitudes and approaches towards teaching and learning informed by game design have been summarized in literature under the umbrella concept of gamification (Christopoulos & Mystakidis, 2023). In education, gamification can be used to transform an indifferent or tiresome procedure into an appealing, enjoyable experience. Game mechanics, dynamics and aesthetics, when applied effectively, can enhance user motivation and produce satisfying experiences (Hunicke et al., 2004).

Immersive technologies have been used widely for the design of serious games in education such as escape rooms games (Voreopoulou et al., 2024). Escape room games have been used effectively to provide skill building opportunities and to facilitate deeper learning around science topics (Vontzalidis et al., 2024). Multiuser, social VR environments can be used for lighter, technically less-complicated gamification strategies to amplify learner motivation (Craig et al., 2016). According to the TANC model, a playful design strategy can be implemented with activities inside of a narrative story within a common semiotic domain, a theme (Mystakidis, 2021).

2.2.1 Discovery-Based Online Learning

Exploration is an inherent mode of human learning experienced in the preschool age. Discovery- or Inquiry-based learning is based on a constructivist epistemological foundation; it facilitates the social construction of knowledge. Inquiry-based learning places the context of education within a quest; learners become the protagonists of their learning and decide their path towards a set goal or deliverable (Mamun et al., 2020). Exploration is one of the most popular game design elements. It activates the players' agency and grants them the freedom to choose their own adventures (Christopoulos & Mystakidis, 2023). Discovery-based methods have been applied in immersive VR environments and virtual worlds effectively in science education (Jacobson et al., 2016; Tsivitanidou et al., 2021).

3 MATERIALS

The Science and Technology Museum of the University of Patras (STMUP) bridges the interaction and communication between the academic community and the local society, especially primary and secondary schools, by providing research-based scientific knowledge dissemination related to cultural tradition. This goal is achieved through various actions including 'temporary exhibitions' (i.e., exhibitions on contemporary topics with a limited lifespan).

3.1 Temporary Museum Exhibition on Greek Revolution

The temporary exhibition "Out of love for Greece" was planned to be hosted by STMUP in 2021 to commemorate the 200-year celebration since the Greek war of independence (or Greek revolution) against the Ottoman occupation (Figure 1). As the COVID-19 pandemic prevented school visits, its digitalization was decided to make its materials accessible to all interested via the Internet. The virtual museum exhibition was based on a digital exhibition initiative by the Institut Français of Greece and RetroNews on the same topic. Materials were modified and transformed into forms that were appropriate and optimized for primary and secondary school audiences.

Figure 1: The poster of the exhibition "Out of love for Greece".

Based on historical evidence in various museums around Europe, in this exhibition, an attempt was made to convey the impact, the various views, and the common feeling caused in Europe by the Greek revolution. Since 1821, everywhere in France, England, Germany, the message of the revolution which was inspired mainly by the ideas of the French revolution, was spreading and expanding. A philhellenic trend was mobilizing public opinion to support the rebellious Greeks. Romantic youth and veteran soldiers were rushing to fight for the Greek cause.

The digital exhibition was enriched by the digital deliverables of transdisciplinary 9-month projects called "thematic networks", in cooperation with K-12 schools, around a relevant, common, topic (Mystakidis et al., 2024).

The exhibition included the following units:

- Philhellenic committees and the mobilization in France and in Europe.
- Portraits of philhellenic volunteers.
- Art joins the battle.
- The educational dimension of the philhellenic movement.

3.2 Development of VR Exhibitions in the Metaverse

The digital museum exhibition was implemented by STMUP in the Metaverse. It was hosted in the free Mozilla Hubs social VR platform based on WebXR technology which allows flexible accessibility through popular web browsers in computers, mobile devices or immersive VR headsets (Maclntyre & Smith, 2018).

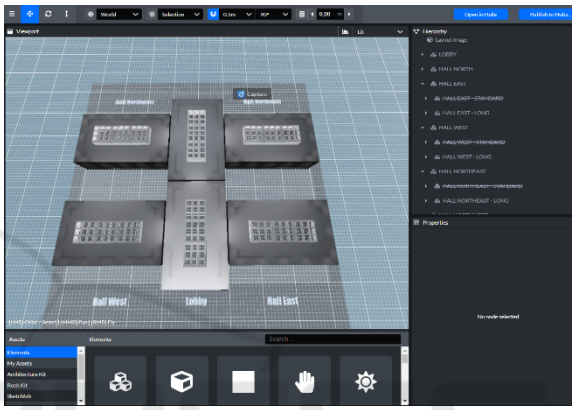

Figure 2: Layout of the VR museum exhibition using a WebXR authoring tool (Scene Editor or Spoke).

The exhibition was hosted in a custom virtual space that was created using the platform's authoring tool. Specifically, Mozilla Hubs provided a free, web-based authoring tool named Scene Editor or Spoke which can be used to create 3D environments, add objects and program custom actions and behaviours.

The created museum space was developed by modifying the template "Modular Art Gallery" that is provided in the Scene Editor. It was configured as a symmetrical H-shaped structure, consisting of four main gallery rooms that are connected through two central corridors (Figure 2). Whole parts of the environments such as entire sections or separate elements such as walls can be edited or replicated (Figure 3). Once the environment is ready it can be published so that it is accessible on the web.

Moreover, in the Scene Editor pre-made 3D objects can be inserted and 2D multimedia materials such as images, pdf files, audio and video can be embedded. However, Hubs also allows the easy creation and manipulation of these digital resources directly from the actual virtual world and their precise placement in desired locations e.g. on the walls.

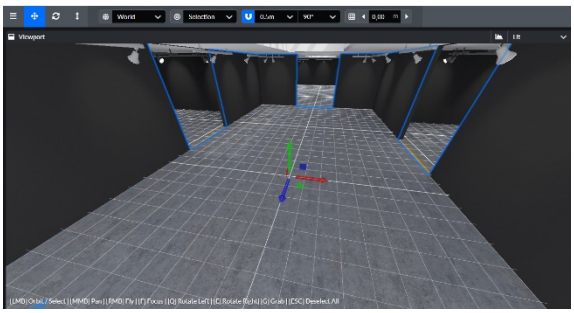

Figure 3: Editing elements of a scene in the WebXR authoring tool (Scene Editor or Spoke).

3.3 Gamified Instructional Design of Exhibitions in the Metaverse

Multiuser Metaverse platforms allow the simultaneous participation of up to 50 users in a 3D environment. Visitors can select and modify a persona or avatar to express their name and identity (Figure 4). This feature is essential to maintain either a desired proximity to users' real identity or to ensure their full anonymity, if it is desirable. Moreover, avatars can roam the place freely, explore and study the materials. Materials included multimedia such as posters, images, presentations, audio and video.

Figure 4: Two personas (avatars) visiting an exhibition of STM in the Metaverse.

The purpose of the virtual exhibition was fulfilled with the digitalization of materials and their online provision, illustrated in Figure 5. However, an additional gamification layer was employed to improve user experience and enhance learners' motivation and engagement. Specifically, a second, playful visiting mode was offered based on the game mechanics of curiosity, discovery and competition.

Avatars were spawn at the virtual entrance of the museum where they encounter a surprise communication. A non-player character in the shape of a monk welcomed visitors and invited them to explore and seek to access a hidden room, a hide-out

Figure 5: Entrance of one gallery room in the VR museum exhibition with portraits of philhellenic volunteers.

of the revolution's heroes (Figure 6). There they could participate in a puzzle game and compete to join the museum's leaderboard.

Figure 6: Playful 'call to action' and invitation to seek the hidden room and gameful challenge.

The hidden room was dedicated to general Kolokotronis, one of the moral and military leaders of the revolution and the long road to freedom after 400 years of occupation (Figure 7).

Users could access it behind an artificial wall. They could discover it based on the symmetrical layout of the overall space. An additional hint was provided in the form of a spatial audio cue, an instrumental music in low volume with sudden sound effects that was echoing from the hidden room.

Figure 7: The hidden room – hideout of Kolokotronis.

Inside the hidden playful room, an optional puzzle game was offered to players. The game consisted of questions based on the materials of the exhibition. The game was conceived as a self-evaluation activity on the comprehension and critical thinking skills of participants.

4 METHODS

In this exploratory study, we employed a qualitative research design approach to evaluate participants' perceptions of the gamified VR exhibition in the Metaverse. The main goal is to uncover the meaning of the studied social procedure. Specifically, qualitative research designs aim at describing, analyzing and understanding in-depth the acceptance and repercussions of the current intervention (Flick, 2018). The guiding research question was the following: What were the perceptions of teachers on a gamified Metaverse museum exhibition in social VR?

The main data collection method was semi-structured interviews with primary school teachers. Secondary data collection instruments were students' observations, students' performance in a post-test, and their comments during a debriefing session.

The teachers' interviewing protocol included a series of questions on the intervention where the exhibition was used during their classes and is provided in the Appendix. Teachers also observed their students' behaviour during the virtual visit to the exhibition. The post-test included eleven questions based on the content of the virtual exhibition and could be found in the hidden room as part of the gamified mode of the exhibition visit. Questions had the form of multiple-choice items, e.g. "How did women become a driving force of the philhellenic movement in Europe and the U.S.A.?", "Why did Eugène Delacroix got involved in the Greek quest for independence?".

Participants in this pilot research were three female teachers from local primary (elementary) schools in Greece that visited the virtual exhibition with their sixth-grade students. The educators were selected based on their expressed interest in the topic of the exhibition and prior work. Detailed instructions on how to access the VR exhibition were provided to educators in advance, as well as the possibility for private one-to-one tutoring sessions for problem-solving. Teachers visited the virtual exhibition during one lesson period (forty-five minutes). Teachers held a short, guided tour with a group of 16 students for approximately 15 to 20 minutes. Additionally, the exhibition's link was provided to students for additional exploration if they wished to. After the visit, teachers held a short reflective debriefing session to collect students' impressions and overall feedback.

Individual interviews with teachers took place online one month after the visit. During interviews, notes were taken and were subsequently analyzed thematically, through the systematic coding approach, to identify common recurring themes within specific categories (Braun & Clarke, 2006).

5 RESULTS

Data analysis of qualitative data revealed several themes that can be organized and classified into the following three categories. Findings are illustrated in Figure 8.

5.1 Insights into Teacher and Student Behaviour

All participants, teachers and students, accessed the WebXR museum environment either via computer, desktop or laptop, or a tablet. They encountered no notable technical problems as the platform was robust with an adequate response time to user movements.

Both teachers and students appreciated the ability to customize their digital representation in the virtual world. This was a feature of interest to almost all students and generated a rich, social, dynamic form of communication and exchange of practices.

The participating teachers were receptive to integrating innovative educational materials into their practice. They were willing to use new forms under the following conditions; learning materials, digital platforms or environments should have: (i) a high degree of usability (ii) low technical complexity and (iii) high pedagogical usefulness, related and supplementary to taught topics. All these conditions were met by the studied VR exhibition according to the study's participants. However, they expressed their wish to have tools in their arsenal that could mitigate eventual problems generated by the total freedom of users. For example, they would like to be able to mute students in case they forgot their microphones open during the online meeting. Moreover, teachers would like to be able to assemble and teleport all users to their location.

Students accepted this type of 3D environment and declared that they would be positive to experience them more often. Students' motivation was dynamic and more diverse. The initial drive when accessing the digital exhibition was to see if and how their own relevant work had been included in the collection and how. It is worth reminding here that participating students had completed a group project on a related historical topic. During the debriefing, around half of students reported that they visited the exhibition again with friends and their parents.

5.2 Student Preferences About VR Exhibition Design

According to the participating teachers, their students offered specific suggestions for the layout of similar exhibitions. Some students with high, inherent interest in the exhibition's topics were satisfied with the layout of the exhibition and appreciated the wealth of presented materials.

Students who had a stronger gaming attitude would prefer less text-heavy materials in favour of audiovisual and more interactive materials. Several of them asked to have the right to download or share exhibited materials. This sparked discussions on the concept of intellectual right of digital creations. In this context, the degrees of freedom granted from creators to the public to allow the sharing, reuse and modification of their work through appropriate licences were discussed. The exhibition of student work was instrumental in raising awareness around sharing and copyright in a creative economy.

5.3 Insights into the Gamification of VR Exhibitions

As mentioned, students had a varying interest in the theme of the digital exhibition. The gamification layer provided an additional incentive that intrigued more than half of the less motivated students to engage with the digital materials and play the game.

Locating the hidden room was not straightforward but most of them were able to locate it thanks mainly to the audio hint. In the knowledge challenge inside the hidden room, mean post-test scores of participating students were 83,3 points out of 110 or 75,7%. This result can be interpreted as very good, reflecting a good command of the presented materials. No notable differences between boys and girls were observed. Interestingly, students reported that they were motivated to revisit the materials and inquire about the facts behind questions to get the answer right. Several users opted spontaneously to play the puzzle multiple times and increased their academic performance.

Several students commented also on the game design of the online exhibition. They advocated for a more complex structure of the 3D environment, e.g. inside of a castle and wished that the gamification layer would have more characteristics of an elaborate game with more levels, challenges and even an adventurous plot. Several children expressed their willingness to learn, experiment and practice with social VR to create their own environments within educational projects.

6 CONCLUSIONS

This exploratory study attempted to capture primary teachers' perceptions about a gamified museum exhibition in the Metaverse. Exhibitions in social VR constitute an alternative and very attractive tool for museums to interact with school groups, pupils and teachers. Moreover, they empower museums to expand and diversify their audience and engage actively with remote visitors. It has supported STMUP to stay in touch with its audience during the pandemic and build new contacts with remote audiences ever since.

This research presents a series of notable limitations. First, the sample of convenience is not generalizable. Second, the studied environment constitutes a proof of concept, not a fully developed solution. However, it offers a series of insights with useful implications for practitioners that can inform the instructional design of educational WebXR spaces.

Social VR platforms are a viable solution for using 3D immersive environments in education as they allow flexible access from multiple devices. Specifically, they are highly appropriate for flexible individual and group study in an asynchronous mode of learning. Synchronous online learning in younger ages can be effective with teacher-centric moderation tools that can minimize eventual distractive effects and behaviours (Rau et al., 2019).

Gamification and playful design can attract young learners' attention and interest to explore with digital content. Game challenges and playful quizzes of appropriate degree of difficulty and complexity can sustain a high degree of engagement. Finally, future efforts and studies can be focused on placing students in the role of producers of immersive content utilizing the potential of 3D virtual reality environments. Museums can explore and implement more procedures to engage pupils and teachers as co-creators of WebXR exhibitions and immersive experiences.

ACKNOWLEDGEMENTS

This research has been financed by the European Union: Next Generation EU through the Program Greece 2.0 National Recovery and Resilience Plan, under the call RESEARCH – CREATE – INNOVATE, project name "iCREW: Intelligent small craft simulator for advanced crew training using Virtual Reality techniques" (project code:TAEDK-06195.

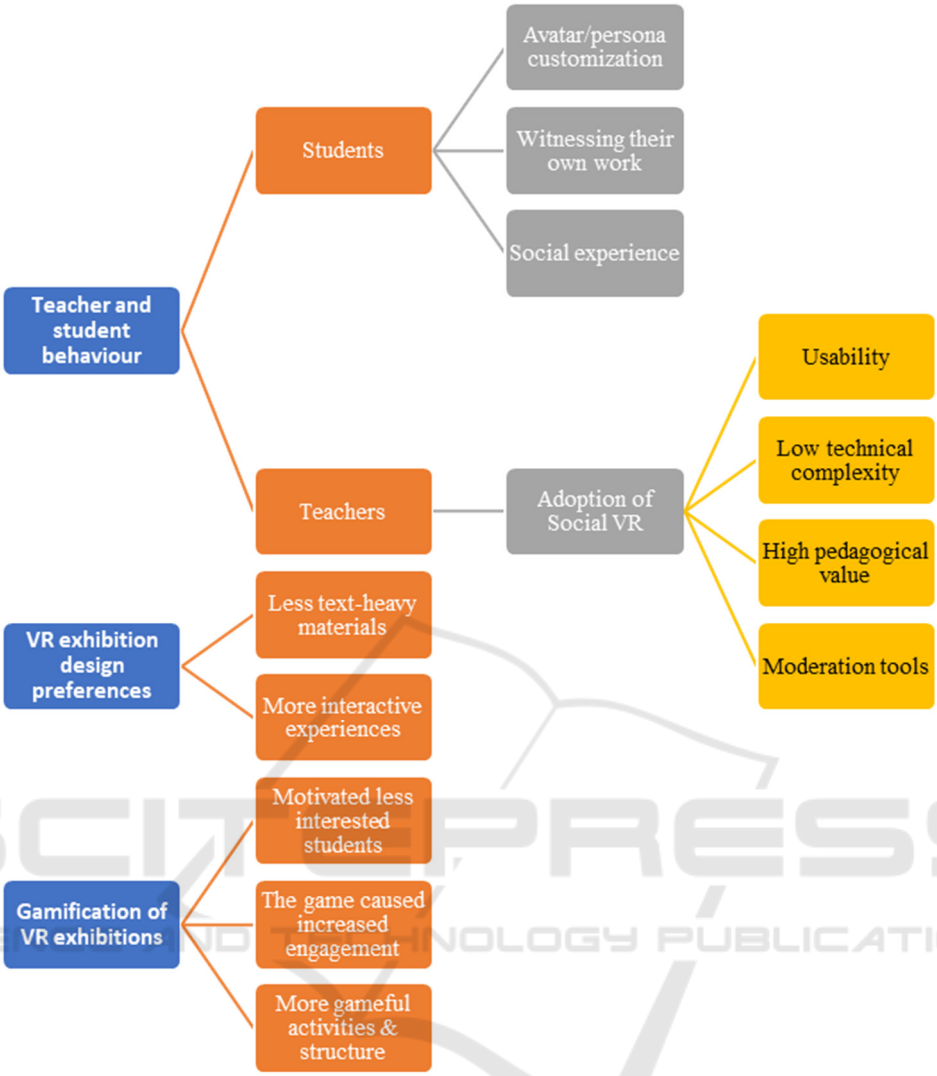

Figure 8: Visual summary and organization of research findings.

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APPENDIX

Teachers' Interview Protocol

1	Ice breaking: Welcoming of the participant, explanation of the aims of the interview and the research.
2	Demographic questions
2.1	Age
2.2	Highest degree of education
2.3	School
3	Main questions
3.1	Total number of participating students
3.2	When did the virtual visit take place?
3.3	What was the visit's duration to the VR exhibition?
3.4	What devices were used by the teacher and students?

3.5 How would you describe the students' behavior and why?
3.6 Did you or students encounter any technical issues or difficulty?
3.7 When did the debriefing session take place?
3.8 What was the approximated duration of the debriefing session?
3.9 What were their impressions of the virtual exhibition?
3.10 Did students have any comments or suggestions for improvements?
4 Epilogue