Enhancing School Visits to Museums through Gamified VR: A Complementary Approach to Learning and Social Engagement

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***Abstract*— Science education faces challenges in engaging students, especially when abstract concepts lack tangible representation. Museums bridge this gap by blending theory with hands-on exploration, but guided tours often remain passive. To increase engagement, this paper presents a hybrid methodology that integrates Gamified Virtual Reality (GVR) with museum experiences. Originally designed to be implemented at the Natural History Pavilion of the University of Almería, the proposed activities, such as "The Intruder" and "Minerals in My Life," encourage students to interact with exhibits through immersive and collaborative tasks. This approach promotes both scientific literacy and social-emotional skills. Although there are technical and financial constraints, partnerships and affordable VR solutions can mitigate these challenges. Future research should explore the long-term impact of this model on interdisciplinary learning.**

Keywords- Virtual Reality; Gamification; Science Museums; Education; Interactive Learning.

I. INTRODUCTION

Science education is essential to develop critical thinking and understanding of the real world, preparing students for life and the challenges of society. However, when addressing these aspects, traditional teaching methods, often centered on lectures and memorization, fail to engage students, especially when faced with abstract and difficult-to-understand concepts [1]. This disconnect is exacerbated in contexts where the lack of practical resources limits the ability to transform theories into tangible experiences, reinforcing the need for innovative approaches.

Science museums, recognized as informal learning spaces, provide a bridge between theory and practice through interactive exhibits [2]. However, even in these environments, many guided tours perpetuate a passive model in which students assume the role of observers, without actively interacting with the content or establishing meaningful connections between the concepts presented and their real-world applications. This limitation underutilizes the educational potential of museums, which could serve as living laboratories for scientific exploration.

The GVR emerges as a response to these challenges, transforming static observation into an immersive and collaborative experience [3]. For example, by exploring digital habitats or identifying minerals in everyday virtual environments, students not only assimilate scientific knowledge but also develop metacognitive skills, such as problem-solving and decision-making. This approach resonates with contemporary demands for Science, Technology, Engineering, and Mathematics (STEM) education that prioritizes digital literacy and prepares students for an increasingly technological world [4].

Furthermore, gamification incorporates playful elements—such as missions, rewards, and healthy competitions—that enhance intrinsic motivation and engagement. When combined with VR, this strategy not only facilitates the assimilation of complex content, but also promotes socio-emotional skills, such as communication and collaboration, which are essential for the student's comprehensive education [5]. By adopting these technologies, museums transcend their traditional role as repositories of knowledge, becoming dynamic spaces where learning is collectively constructed, and not just transmitted. This transformation, however, does not occur without obstacles. The effectiveness of GVR depends on careful pedagogical design, which avoids prioritizing technical aspects to the detriment of clear educational objectives. Furthermore, new technological tools to support education cannot focus on merely virtual and individualistic learning, since access to available physical resources and interaction with peers throughout the learning process are also essential. Therefore, aligned with the needs of students and the principles of experiential learning, this proposed methodology represents a significant advance in the way we conceive the relationship between education, technology and social engagement.

The paper is structured as follows. In Section II, the state of the art on VR and gamification in museums is presented. In Section III, the hybrid methodology and the respective proposed activities are detailed. In Section IV, the benefits, challenges and expected outcomes are discussed. Finally, conclusions and future directions are addressed in Section V.

II. STATE OF THE ART ON VR AND GAMIFICATION IN MUSEUMS

The integration of VR into museum experiences has gained significant attention in recent years. Studies highlight

its potential to transform traditional museum visits by increasing interactivity and engagement through immersive digital environments [6],[7]. Research in this domain typically focuses on leveraging VR to enhance individual learning experiences, allowing visitors to explore historical reconstructions, scientific simulations, and cultural heritage artifacts in new ways [8]. Gamification can further enhance these experiences by incorporating elements such as challenges, rewards, and collaborative quests, effectively increasing motivation and knowledge retention [9]. Several studies show that combining VR with gamified strategies promotes cognitive and socio-emotional gains [10], [11]. Despite these advances, the application of hybrid VR models that integrate physical and digital museum visits remains underexplored. Most studies on this topic emphasize fully immersive digital content or augmented on-site enhancements without a connection between the real and virtual environments [8]. A crucial gap in current research is the lack of strategies that facilitate social and cooperative learning in VR-enhanced museum environments. Although collaborative VR applications exist in other educational contexts, their adaptation to school group visits remains minimal, limiting their potential to support teamwork, communication, and collective problem-solving [9]. This study addresses these limitations by proposing a model that merges physical museum visits with collaborative GVR tasks. Unlike previous approaches, the methodology proposed in this paper offers active and collaborative participation to solve educational challenges, demonstrating the potential of structured hybrid VR models to enrich science education beyond traditional classroom settings.

III. METHODOLOGY

The proposed hybrid methodology was developed in response to the demand for virtual reality experimentation with school-age children, integrating both physical and virtual visits to the Natural History Pavilion at the University of Almería. The concept was designed around two GVR activities:

• The Intruder: After physically visiting the museum's display cases, which showcase different plant and animal habitats, students use VR headsets to explore the same environments, now virtually modified. Their task is to identify misplaced species by comparing them to the physical specimens previously observed. Meanwhile, classmates actively participate in resolving discrepancies between the virtual and real displays.

• Minerals in My Life: Similar to the previous activity, students first visit the museum's collection of stones and minerals, learning about their primary applications in daily life. They then explore VR-based residential and workplace environments featuring commercial products and equipment that incorporate minerals as raw materials. The gamified activity, conducted collaboratively with peers, involves identifying the minerals present in various everyday objects within the virtual environments.

The design of the these idealized activity models is based on collaborative VR structures and gamification strategies that have been shown to enhance engagement [10] and improve the contextualization of scientific concepts through situated learning [11]. Beyond the museum's physical resources, implementing the gamified activity requires a 360° camera for capturing the images, a platform for creating a virtual tour, and VR headsets. Additionally, the creation of pre- and post-activity assessments is essential for evaluating conceptual understanding and teamwork, aligning these evaluations with cognitive and socio-emotional assessments while also providing feedback for refining the model.

IV. BENEFITS, CHALLENGES AND EXPECTED OUTCOMES

The proposed hybrid methodology offers substantial advantages for science education. By integrating collaborative VR tasks into museum visits, students transition from passive observers to active participants in dynamic problem-solving scenarios that mirror real-world scientific challenges. The immersive nature of VR enhances intrinsic motivation, as gamified activities are perceived as inherently engaging and rewarding. This leads to greater student involvement and improved knowledge retention compared to traditional observation-based learning. Additionally, the interactive design fosters peer-to-peer learning, enabling students to exchange ideas, critique hypotheses, and refine solutions through discussion, thereby strengthening both cognitive and social skills.

Despite these benefits, the implementation of this approach presents several practical and pedagogical challenges. One major obstacle is financial: high-quality VR hardware can be cost-prohibitive for institutions with limited budgets. While low-cost alternatives, such as smartphone-based VR viewers, offer a potential solution, their impact on immersion and interactivity must be carefully assessed. Moreover, sustaining these initiatives requires strong institutional partnerships. Without such collaborations, scalability remains a significant hurdle, particularly for smaller institutions. Another critical concern lies in the design of the gamification itself. If not carefully structured, gamified elements risk reducing learning to a superficial competition for points or badges rather than fostering deep educational engagement. Addressing these challenges demands meticulous planning, continuous teacher training, and iterative feedback mechanisms to fine-tune the balance between engagement and educational rigor while optimizing the relationship between real and virtual learning.

The implementation of the proposed hybrid methodology is expected to yield several positive outcomes. First, it aims to enhance student engagement by transforming conventional museum visits into interactive and participatory learning experiences. By incorporating VR-based gamified tasks, students are likely to exhibit higher motivation and improved retention of scientific concepts, as previous research indicates that immersive learning environments facilitate deeper cognitive processing. Furthermore, this approach is expected to promote collaborative problem-solving skills, as students work together to complete tasks

and explore real-world applications of science. Another anticipated outcome is the development of socio-emotional competencies, including communication and teamwork, as peer interaction plays a fundamental role in the learning process. Finally, this methodology has the potential to serve as a scalable model for other educational institutions, paving the way for further research into the long-term impact of GVR in science education.

V. CONCLUSIONS AND FUTURE DIRECTIONS

This study introduced a hybrid methodology that integrates GVR into museum experiences, aiming to transform traditional visits for student groups into immersive and participatory activities. To this end, practical activities were designed based on principles of gamification, situated learning, and collaborative participation, utilizing resources such as physical visits, 360° VR, and pre- and post-activity assessments as feedback mechanisms to refine the methodological design. The approach promotes active engagement, integrates theoretical knowledge with practical applications in a playful way. Collaborative tasks in VR, when integrated into the physical environment, not only facilitate the retention of complex scientific concepts but also enhance socio-emotional skills, such as communication and teamwork. As museums evolve into dynamic and interdisciplinary centers, it is crucial not only to adopt technological innovations but also to implement them within contexts that foster meaningful learning for comprehensive and inclusive education, thus exploring the full potential of these simulation tools.

For future guidance, it is recommended to investigate the long-term impact of this methodology as an interdisciplinary resource and promoter of skills and competencies. Comparative studies across different age groups and socioeconomic contexts could enhance the inclusiveness of the model. Additionally, it is essential to explore the integration of artificial intelligence and sensors such as eye tracking in VR to personalize experiences and improve real-time feedback. Finally, expanding the model to other exhibition spaces related to art, science, and history could consolidate the role of museums and galleries as dynamic environments for pedagogical innovation, aligning them with the advancements in VR and the growing emphasis on creating immersive worlds for education and culture.

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