Space Exploration Museum with Virtual Reality

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***Abstract*—This research paper documents the development and ongoing testing of a Virtual Reality (VR) modern museum experience for people of all ages, especially those who face financial or physical barriers to visiting traditional institutions. This paper is a continuation of the Metaphysical Exhibition project, which aims to provide a cost-effective and easily accessible alternative to physical museums by utilizing VR technology that can be accessed with a one-time purchase of hardware and free software. The virtual museum is portable and can be experienced anywhere. Our focus is on developing a VR museum about space exploration and assessing its impact on users. Through our planned study, we aim to answer three key questions: (i) How does the VR museum experience compare to that of a physical museum? (ii) What is the level of interest and engagement in self-guided VR content for educational purposes, from both students and teachers? (iii) How can the VR museum experience be enhanced to optimize learning outcomes and user satisfaction?**

***Index Terms*—Virtual Reality, Space Exploration, Education, Unity 3D, Museum**

I. Introduction

A STEM (Science, Technology, Engineering, and Mathematics) education is critical for preparing students for the workforce of the future. The demand for professionals with STEM skills is increasing rapidly, and it is essential that students have a strong foundation in these subjects to compete in the job market. Exposure to space exploration can ignite an interest in STEM among students, as it provides a real-world application for these fields. The exploration of space requires a wide range of expertise, from designing and building spacecraft to conducting experiments and analyzing data. By introducing students to the exciting world of space exploration, educators can show them how STEM concepts are used to solve complex problems and make significant discoveries.

Moreover, space exploration has many practical applications that can benefit society in numerous ways. Advances in space technology have led to innovations such as GPS and satellite communication, which are now integral parts of our daily lives. Students who are inspired by space exploration may be motivated to pursue careers in fields such as aerospace engineering, astrophysics, or planetary science, where they can make meaningful contributions to society. By fostering an interest in STEM through space exploration, educators can help prepare students for the challenges and opportunities of the future while also encouraging them to explore the wonders of the universe.

Our application aims to foster an interest in STEM topics through a virtual reality based museum. This museum will introduce students to space and space exploration topics through interactive scenes. These scenes will allow students to explore and learn about specific topics, including but not limited to the Apollo 11 mission, the Curiosity rover, and the Hubble telescope. Students will be evaluated on their comprehension of the topic by taking short quizzes, which we refer to as educational modules. Each module gives students insight about the topic and then tests their comprehension through simple recall questions. With a focus on immersive exploration and light testing, we aim to create an application that will foster student's interests in space and STEM as a whole.

A. Questions and Importance

The questions pertaining to our research are as follows:

- Does experiencing the museum in this format feel analogous to prior exhibit experiences?
- What is the level of interest in exploratory, self-guided VR content used in education from both a student and teacher perspective?
- What features or topics are missing from this application?
- How can the experience be improved?

These questions have been constructed expressly to relate to the primary topic of educational potential. Ultimately, the project is focused on determining if a virtual museum application, as described, would be of use to educators and students.

We hope to provide the scientific community with several foundational elements for future research. (i) A study across a wide age range, from Middle School to University, (ii) Further generalization of exploratory VR as an educational medium, and (iii) Information concerning not only the viability of the medium but also metrics of educator and student intrigue and user comparisons against precedented formats.

B. Background and Terminology

To contextualize the topics of this paper, we define our implementation of Virtual Reality (VR) as a tracked headset and controllers with six degrees of freedom, such as an HTC Vive, Valve Index, or Meta Quest 2. This is in contrast to more limited implementations of VR, such as the older Oculus models or experimental Google Cardboard.

C. Organization

The paper is structured as follows: Section I-D provides a comprehensive discussion of prior implementations of the VR museum concept, including educational offerings from NASA and other institutions. Section II outlines the methodology used for designing the application, including layout, sourcing of materials, optimization for target devices, and feedback collection. A plan for gathering survey results is given in Section III, followed by a detailed explanation of planned improvements for the application in Section IV.

D. Related Works

Using digital experiences to teach space sciences has been explored in the past but primarily through traditional two dimensional interfaces, like web pages and smartphone applications. There have been some notable space virtual reality projects, but as of now the dominant media is a standard two dimensional display.

1) Web or Mobile Experiences: NASA has many web pages dedicated to various programs underneath their agency with a range of complexities. We will focus on pages dedicated to virtual educational experiences, of which there is one primary page, the *NASA at Home* page, which details various activities and resources from NASA that can be experienced entirely virtually [1]. From these resources, there are a few 360 views, but primarily static pages or YouTube videos. Two resources of note are the Exoplanet Travel Bureau and NASA's Exoplanet Excursions, both of which are more focused on interactive and immersive exploration [2]. These opportunities focus on singular exoplanets or telescopes and take deep dives into each subject. This differs from our application, as we focus on a wider spread of information at the disadvantage of less detailed explorations. Another web experience, Experience Curiosity, similarly differs in that it focuses solely on the Curiosity Rover, but has more depth and higher interactivity than our offering [3]. NASA's Jet Propulsion Laboratory has published several mobile applications that fall under the same topic as the museum. These include Spacecraft AR, and Earth Now [4]. Spacecraft AR focuses on using augmented reality to display and teach about various spacecraft, whereas Earth Now provides real time information about the globe in a visual manner. As with prior discussed applications, these offerings are more limited in scope than our proposed application, as well as being in a different medium.

2) VR Experiences: Firstly, there is a limited time VR experience called Space Explorers: The Infinite that uses 360 degree footage aboard the ISS to immerse participants in the space craft environment [5]. A similar offering titled Space Explorers presents the same concept, with 360 degree videos of the ISS and a space walk used to immerse the viewer [6]. There are several differences between the offerings here and the proposed application, primarily in the usage of VR. Our proposed application does not use recorded 360 degree media, rather, we use explorable 3D environments. There pros of using 360 degree video is fidelity and realism, with the con of locked position and loss of interactivity, both of which our application relatively excels in. The primary VR offering from NASA comes from the Jet Propulsion Laboratory with Spitzer VR, a VR experience focused on the Spitzer telescope [7]. This application is the closest to our proposed application, as it uses the same targeted platforms, has a fully 3D VR environment, and has educational modules inside said environment. Still, as all applications listed above, the scope is more limited than our offering, but with the same pros as the other competing offers - more depth and technical expertise in the subject.

3) Studies: As for the precedence of VR as an educational medium, a foundational study examining the efficacy of virtual reality museums determined that after the initial wow factor of VR, there was no significant difference in immersion or interest between a real, traditionally designed museum and its digital replica [8]. Additionally, a comprehensive study on VR in education concluded that the applications of VR in the classroom are incredibly promising, writing: "The main advantage of IVR seems related to the possibility for users to have first-hand experiences that would not be possible in the real world … simultaneously offering unique opportunities for experiential and situated learning, as well as promoting students' motivation and engagement" [9]. This field study strongly supports the museum-experiential-learning hybrid application that is in development [10]. Based on these findings, it is reasonable to believe that a virtual museum designed to enhance STEM education through experiential learning would have a positive impact on the target demographic's interest in STEM education.

II. Methodology

A. Application Design

1) Targeted Platform: The Meta Quest line, starting from the Meta Quest 2, is the targeted platform for two primary reasons: cost and portability. The Meta Quest 2 is relatively cheap at a current retail price of 400 USD. Being an all-in-one system, it is easy to transport and simple to set up for a classroom setting. As the application is built to be used by all ages in a wide range of settings flexible portability is a necessity. Without the complications of a tethered setup and high computation requirements associated with other VR platforms the barrier to entry is lowered as much as possible for educators and general consumers. To reiterate, in a classroom setting portability and cost are crucial to adoption and frequent usage.

2) Game Engine and Frameworks: It was decided to develop the application on the Unity platform for two primary reasons: accelerated development and device-agnostic code. Unity is a robust game engine explicitly designed to be multi-platform compatible and easy to develop. Another reason Unity was chosen for development is the Unity XR Toolkit, a cross-platform framework that allows for relatively painless scripting that will interface with any VR headset technology seamlessly.

This means that it is simple to port the application to other virtual reality devices. In development, the software was tested and validated on two headsets, the HTC VIVE and Meta Quest 2. During testing, the application was built for both Windows and Android. During migration of the build platform no changes to the underlying code had to be made and the transition was completely seamless, meaning that our goal of cross compatibility has been achieved for our target platforms.

Using the Unity XR Toolkit, we are able to write code that should work with any supported VR device and platform. The majority of code for this project was written in C#, with some scripting in Java Script for data retrieval and database operations.

B. Museum Design

The application currently features five scenes: the Hub, the Planets, the Moon, Mars, and the Hubble telescope. Each of these scenes provide different experiences to the user while all scenes contain educational modules. This paper will focus on the two most complete, the Hub and the Moon.

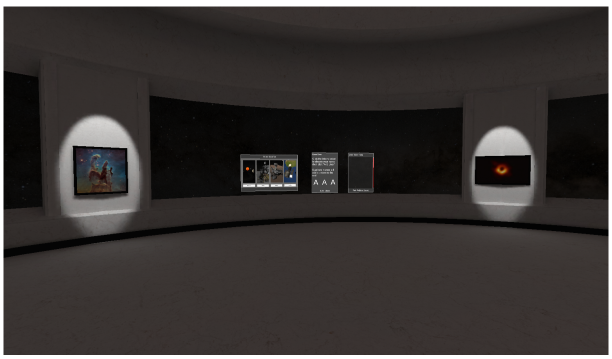

Fig. 1. The Hub scene, showcasing the scene selection in the center left, user entry to the center, and user history to the center right. On the far left is an image of the Pillars of Creation, on the far right the First Image of a Black Hole.

1) The Hub: The hub scene (Fig. 1) is most analogous to a menu. Within the hub users can log in or out as well as view previous answer history. This allows for users to keep track of completed modules and gives a clear overview of what more is left to explore and learn in the scenes. This system sets the foundation for a more comprehensive reporting tool. The hub contains five framed photos and one object, each of which has an accompanying module that describes the object and provides a comprehension quiz. From the hub the user has the option to visit any of the other four scenes.

2) The Moon: The Moon scene (Fig. 2) transports the user to a representation of the surface of the Moon. This fabricated surface is made to imitate the real surface of the moon, including scattered Moon rocks taken from 3D scans of lunar samples sourced from the NASA Johnson Space Center Astromaterials Research & Exploration Science division [11]. In this scene, the user can view a replica of the Apollo 11 lunar lander, a recreation of the first step, and a panorama of the real surface of the Moon taken from the Apollo 11 mission. There is an educational module introducing users to the surface of the Moon with a focus on the Apollo 11 mission. As with all other scenes users are free to explore their surroundings and travel to any other scene via a scene selection menu.

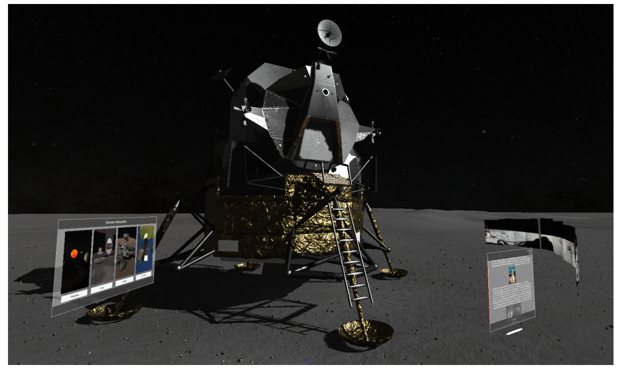

Fig. 2. The Moon scene, with a recreation of the Apollo 11 Lunar Lander in the center, a panorama of the lunar surface on the right, the back view of an educational module in the lower center, and a scene selection menu on the left.

C. Information Sourcing and Copyright

All information present in the application is licensed either under Creative Commons 0 (CC0) or a variation of Creative Commons Attribution (CC-BY). During the process of creating the application we carefully considered the licensing and legality of information in all cases. Attribution is given in the cases of CC-BY, and in most CC0 cases even when not necessary so as to respect the original authors. It is a primary goal of the project to maintain an open license so others may improve on it in the future without concern of copyright. A vast majority of the information used in the creation of the application is sourced from various NASA and EAS publications under the CC0 or comparative licenses. Without the permissive licenses on this information, creation of the application would have been greatly hindered.

1) Movement and Accessibility: The movement system for the Metaphysical Museum is both standard and flexible. It allows for room-scale movement, ray-based teleportation, and snap-turning for anti-nausea orienting. Many of the modules can both be moved around the player as well as follow their physical movements, allowing for them to orient its position to their comfort.

III. Collection of Feedback and Results

The collection of feedback and results is ongoing and will target a younger demographic. Participants are expected to be within the K-12 to Undergraduate level, covering a wide swathe of the educational demographic. Feedback refers to a survey given to participants which asks the users to share their opinions about what they liked and disliked about the application. Results will be gathered by having participants taking a short quiz on the content of the museum before and after using the application. For privacy reasons, users' identities will not be collected, rather they will only be identified by a unique number. No personal information will be collected, with the exception of age and gender.

A. Analysis of Results

The main form of analysis planned is to plot the average results on the quizzes for each age category, to find which age group this tool is most effective for. Quiz results will be quantified individually by subtracting initial score from the final score. For example, a participant who got a 70% on the first quiz and a 90% on the second quiz, would have an improvement score of 20%. Likewise, if the first and second scores were reversed, their improvement score would be -20%. These scores will be averaged both overall and per age group.

IV. Future Works

A. Introducing More Interactivity

The experience is already quite immersive; however, there is significant room for improvement in terms of interactivity. For example, audio tours would greatly enhance the interactivity, utility, and immersion of the application.

B. Expansion of Accessibility

It is important that the application is as accessible as possible within the constraints of VR. One simple addition is a height adjustment feature so that people who are seated are able to experience the museum the same as people who are standing. More options for stick based navigation would also increase the potential user base. Mobility should not be a hindrance in a VR experience.

C. Data Collection and Analysis

As we finalize this stage of the application, extensive testing and subsequent data collection will be carried out. This data will allow us to properly address the initial questions laid out in this work, at which point we may draw more accurate conclusions. As of now, we are working with a small preliminary set of data that cannot accurately give insight into the application.

Conclusion

With believe that with the feedback and results we gather from our preliminary study, as well as the above mentioned changes, we will be able to improve both the educational value and user friendliness of the application. After we have made the changes that our feedback has lead us to implement, we will likely pursue a second study to quantify how the changes made affected users' experience with the application..

References

[1] B. Dunbar, "Nasa at home," NASA at Home. [Online]. Available: https://www.nasa.gov/specials/nasaathome/index.html

[2] E. E. Program and N. J. P. Laboratory, "Exoplanet travel bureau," Exoplanet Exploration: Planets Beyond our Solar System. [Online]. Available: https://exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau/

[3] B. Kumanchik and N. J. P. Laboratory, "Experience curiosity," NASA's Eyes. [Online]. Available: https://eyes.nasa.gov/curiosity/

[4] V. T. Applications and D. Team, "Nasa's eyes: Mobile apps," NASA's Eyes, 2023. [Online]. Available: https://eyes.nasa.gov/mobile-apps.html

[5] T. I. Experiences, "Space explorers: The infinite," Space Explorers: THE INFINITE, 2023. [Online]. Available: https://theinfiniteexperience.world/en/montreal

[6] F. . P. Studios, "Space explorers," Meta Quest, 01 2020. [Online]. Available: https://www.oculus.com/experiences/quest/3006696236087408/

[7] N. J. P. Laboratory, "Spitzer vr," Spitzer Space Telescope. [Online]. Available: https://www.spitzer.caltech.edu/explore/spitzer-vr

[8] J. Marín-Morales, J. L. Higuera-Trujillo, A. Greco, J. Guixeres, C. Llinares, C. Gentili, E. P. Scilingo, M. Alcañiz, and G. Valenza, "Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum," *PLOS ONE*, vol. 14, no. 10, pp. 1–24, 10 2019. [Online]. Available: https://doi.org/10.1371/journal.pone.0223881

[9] A. F. Di Natale, C. Repetto, G. Riva, and D. Villani, "Immersive virtual reality in k-12 and higher education: A 10-year systematic review of empirical research," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2006–2033, 2020.

[10] J. Maddy and H. S. Narman, "Virtual reality museum application for the arts," in *2023 IEEE Integrated STEM Education Conference (ISEC)*, 2023, pp. 286–292.

[11] N. A. R. . E. Science, "Astromaterials 3d," Astromaterials 3D. [Online]. Available: https://ares.jsc.nasa.gov/astromaterials3d/