Webb Space Explorer: Enhancing Astronomical Learning Through Interactive Technologies

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1 ABSTRACT

The Webb Space Explorer is an innovative educational tool inspired by the story of the James Webb Telescope. We designed the Webb Space Explorer to simulate spaceship movements in the solar system. The aim is to increase public awareness of the solar system. The platform combines gyroscope and interactive website technology, dynamically showing the movements of the solar system to create an immersive study environment. The Webb Space Explorer adopted a multi-sensor system incorporating visual, hearing, and tactile elements, voice explanations, and text descriptions. Webb Space Explore transforms passive-absorbing knowledge into active learning and exploring. Our questionnaire and quiz results show that users who engage with the Webb Space Explorers have 10% higher quiz performance than those who only use the website[study]. Furthermore, Webb Space Explorers' interactive and dynamic features allow users to spend more time on the product than the traditional website, with an average of 1.5 minutes more.[study]The Study indicates that users are willing to engage and explore the Webb Space Explorer. In summary, the Webb Space Explorer is an integrated educational platform that applies its interactive functionality, providing users with an engaging and informative user study experience.

2 INTRODUCTION

Museums play an essential role in protecting, displaying, and interpreting cultural heritage [4]. These include modifications to the forms of museum exhibitions and the growing use of technology with audience participation and the interpretation of artwork and artefacts [1].

Although modern VR (virtual reality) and AR (augmented reality) technologies[5] bring immersive visual experiences to museum exhibitions, they have certain interactive limitations. Specifically, although users can see the exhibition's three-dimensional model and feel the exhibits' environmental atmosphere through VR and AR, this experience is mainly visual and auditory, lacking direct interaction with touch and other senses. This means that although users can "get closer" to the exhibits in the virtual environment, they cannot touch or interact with them in a physical way, which may somewhat reduce the effectiveness of deep learning and exploration. Although this technology dramatically enriches the audience's experience and makes the educational content more vivid, it also needs to consider improving

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Fig. 1. Current mainstream museum exhibition methods

interactivity so that users can understand and feel the exhibits more deeply, thereby learning and absorbing knowledge more effectively. Further developments in technology may address these issues, such as enhancing the user experience through haptic feedback and advanced interactive devices.

The "Webb Space Explore" project aims to introduce incoming gyroscopes and interactive websites to fix these problems. The goal is to stimulate an interactive space-exploration experience to increase the public's interest in space and make it more interactive and sensor-engaged. Using a 3D print of the James Space Webb Space Telescope, a gyroscope module and an interactive website based on HTML, CSS and Javascript, We created an educational platform that allows users to control the spaceship and explore the solar system.

The James Webb Space Telescope was launched on 25 December 2021 [25], becoming the greatest and one of the most expensive, costing 10 billion US dollars [25]. James Webb Space Telescope aims to uncover the mystery of the universe [26]. It has made some breakthroughs in all the fields of astronomy. Based on the critical role of the James Webb Telescope in the history of science and the development of astronomy [7], we selected the James Webb Telescope as the research object for the physical part of the WebbSpace Explorer project.

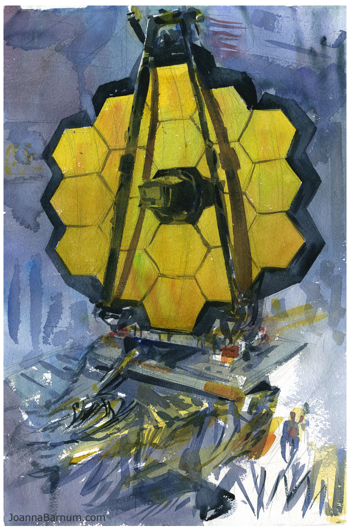
At the same time, our projects also assess their impact on visitor engagement and learning outcomes, which might contribute to the emerging field of intelligent museum exhibitions. Previous research on the effectiveness of interactive devices in museums, such as "Interactive Devices in Museum Exhibitions: Enhancing Visitor Learning and Engagement" [9], provides the basis for our evaluation strategy. For example, we used the designs of Studies 1 and 2 to obtain qualitative research data for evaluation.

This project combines 3D printing technology, gyroscope positioning technology, and interactive website design to develop WebbSpace Explorer. It shows great potential to increase audience engagement and improve accessibility for various visitors, creating more inclusive and enriching interactive museum experiences. Through WebbSpace Explorer, we will examine user reactions to this new way of museum interaction from the perspective of museum visitors and reflect on the realization of our desired reshaping of the relationship between museums, collections, and audiences.

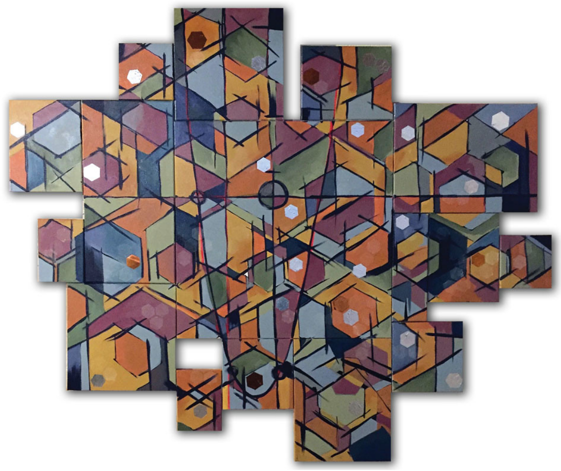
3 RELATED WORK

3.1 JWST Art Exhibitions

Recent collaborations between the art world and NASA highlight the potential of using art to raise public awareness through science [15]. One example is an exhibition at NASA's Goddard Spaceflight Center in Maryland, where 25 artists created works inspired by the James Webb Space Telescope (JWST) [15]. Through this project, artists use various media, including poetry, sculpture and watercolour, to explain the telescope's design and mission. In addition to providing a venue for artistic expression, the exhibition engages the public in understanding JWST's scientific mission through emotional and visual narratives.



(a) Painting 1



(b) Painting 2

Fig. 2. Two Paintings at the Exhibition[14]

3.2 Interactive museums

Some exhibition technologies, such as virtual reality (VR) and augmented reality (AR), have already been used in some museums [12][13]. These technologies offer visitors new ways to interact with exhibits. However, studies such as "Enhancing the Museum Visitor Experience through Immersive Technologies" [3] show that they often lack direct physical contact, which can diminish a sense of connection to the exhibits. While museums such as the Natural History Museum [16] and the British Museum [17] have used AR and VR to provide more immersive storytelling, these experiences often focus on visual and digital aspects, limiting the possibility of in-person participation. For example, the interactivity offered by VR and AR is limited to what the software allows. This may limit visitors from exploring the exhibits at their own pace.

The Cornwall Museum Partnership provides examples of how combining digital technologies with local art, such as interactive displays [18], may significantly improve the tourist experience. These projects show how innovation and technology may work together to change static museum halls into dynamic settings that provide deeper cultural interactions.

3.3 Using 3D printing to restore museum relics

Archaeologist Néstor Marqués[19] has been experimenting with 3D printing technology since 2012, combining his love of technology with his passion for archaeology and innovatively applying it to the field of archaeological restoration. Marqués creates full-scale, intricate replicas of historical artefacts to enhance the tactile experience for museum visitors. This approach not only enables ancient artefacts to be restored and re-presented in entirely new ways but also provides museum visitors with the opportunity to interact with ancient history, enhancing the educational and engagement value of the exhibition.

His method's main component is photogrammetry[19], which scans and virtualises artefacts. Simplify3D software can create printed three-dimensional models. This software allows precise control over printing, which is crucial for achieving the high-quality replicas Marqués produces. He has completed notable projects, including a replica of a 2,300-year-old statue over four feet tall, assembled from twenty-one pieces for Vilamuseu in Spain. At the same time, the original remained at the National Archaeological Museum of Spain.

3.4 Contribution of This Work

By combining gyroscope technology, 3D-printed replicas, and an interactive website to provide a hands-on experience of operating a virtual spaceship, our project, WebbSpace Explorer, fills in these gaps. Through direct connection with the displays and the stimulation of numerous senses, this technique improves the interactive aspect of museum exhibits and enhances educational outcomes [20]. By doing this, We suggest a fresh model for instructional materials in museum settings by utilizing the JWST's teaching potential in a way that earlier shows have not.

4 DESIGN & IMPLEMENTATION

4.1 Initial Prototyping

The possible interactive features for creating an interactive exhibit for the JWST are diverse and many. We had 3 initial ideas:

- **Interactive replica with buttons:** This involves having a 3D-printed replica for the JWST, where we will include interactive buttons for users to press and hear information.
- **AI-assistant smart replica:** This refers to having an AI chat assistant incorporated into the 3D printed replica, where users can interact and ask questions. This aim is to enhance the interaction with the physical prototype
- **Projection imagery:** For example, a projection where participants can see our solar system or galaxy formations.

Thus, we tested these 3 ideas by carrying out a preliminary study.

4.2 Preliminary study

The objective of this preliminary study is to determine users' level of knowledge of telescopes and their interest level in possible features of the Webbspace Explorer. The questionnaire was sent out as a Microsoft form, and the participants were recruited by sending the link to our classmates, teaching assistants, and professors.

Ten participants were gathered to take part in the questionnaire. Seven participants were students aged 18 to 24, 1 participant was 35-44, 1 participant was 45-54, and 1 participant was above 55. The participants identified as male (n 4), female (n 5), and other (n = 1).

We created an online questionnaire with nine questions: We asked users to rate how much they enjoy going to museums and the genre of museums they enjoy going to. This is to verify that the participants are at least interested in science museums before asking for their interest level in possible features of the Webbspace Explorer. We asked participants to rate their familiarity with a telescope and what aspects of a telescope they were more interested in. Participants had to rank which proposed features in the Webb space telescope excited them the most. At the end, there was an open-ended question for participants to suggest any ideas they had.

The average time taken to complete the questionnaire was 2 minutes. 70% (7/10) of the participants liked or loved going to museums, where science museums were rated the top favourite genre. 80% of the participants had minimal knowledge about telescopes and had never used a telescope before. Astronomy and galaxy formation were the top-rated aspects of the telescope that the participants were interested in learning more about. For the proposed features of Webbspace Explorer, the top 3 were in this order:

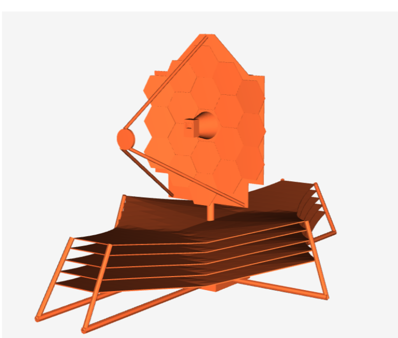
1. Projection of the galaxies
2. Tilting the telescope changes the image of the projection.
3. Interaction between the sun and the telescope.

These results reveal a few important insights: We had to design Webbspace Explorer to be intuitive for inexperienced users, as the questionnaire showed that the participants needed more experience or knowledge about telescopes. The content of the Webbspace Explorer should be centred more on the aspects of astronomy and galaxy formation, but it should also remain easy to understand. The features that attract users the most are a projection of galaxy formation and more hands-on interaction with the exhibit rather than just learning about the content via audio outputs.

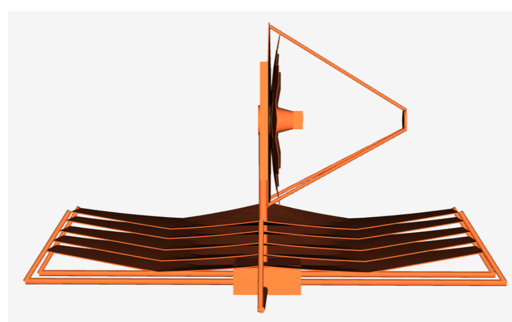
Hence, we will take this feedback into the subsequent design of Webbspace Explorer. The Webbspace Explorer will thus settle on our third idea of having projection imagery. To enhance the interactive experience of the participants, we will also add the feature of "Tilting the telescope changes the image of the projection" to the Webbspace Explorer.

4.3 Design Implementation

4.3.1 ***3D Printing and Assembly:*** The construction phase began with obtaining the STL model file of the Webb Space Telescope from an online repository [27]. We modified the file dimensions to accommodate the Arduino control board, providing a customized housing for the Webb Space Explorer. The Arduino board and gyroscope were then integrated seamlessly into the 3D-printed structure.



(a) Front view of the telescope



(b) Side view of the telescope

Fig. 3. Front and side views of the telescope displayed side by side

4.3.2 ***Hardware Design.*** Early in our Webspace Explorer project, we decided between the Arduino Uno and the Arduino Nano. Ultimately, we chose to use the Arduino Uno as the main control board for the following key reasons:

- **Ease of Use and Newbie-Friendly:** The Arduino Uno's larger size and clear pin labels make operation and understanding more accessible, especially for novices. This simplicity aids learning and development.
- **Powerful Functionality and Extensibility:** Compared to the Arduino Nano, the Uno provides more power and ground pins, simplifying the addition and management of new sensors and components. This extensibility is crucial for anyone wishing to replicate or further develop our project.
- **Module Compatibility and Ease of Integration:** Although the Arduino Uno is larger, it is more compatible with many other modules, which eases the integration of additional modules. Measuring approximately 68.6 x 53.4 mm, the Uno offers more flexibility in physical integration than the smaller Nano.

The Arduino Uno's ease of use, robust functionality, scalability, and better module compatibility make it an ideal choice for our Webb Space Explorer project.

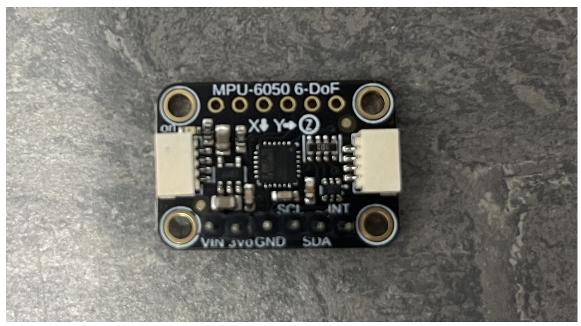


Fig. 4. MPU-6050 gyroscope module

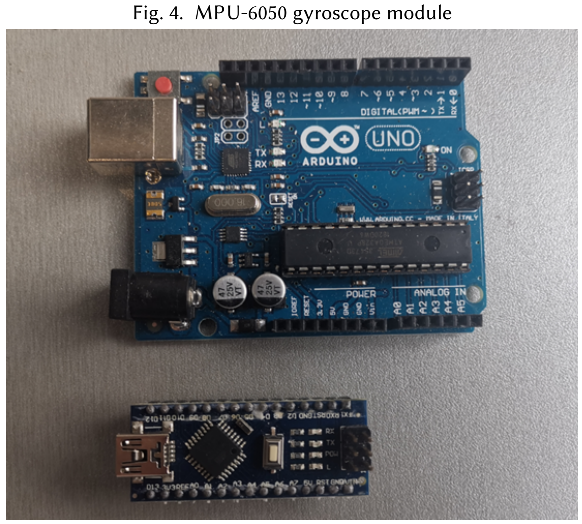


Fig. 5. Arduino Uno on the top with Arduino Nano on the bottom

4.4 Software Design: Version 1

Our primary objective was to use gyroscope-transmitted data to control a 3D model of the JWST spaceship, aiming to simulate the spaceship's rotations and positional changes within a dynamic solar system environment.

Utilizing the Processing platform, we incorporated a graphical solar system backdrop with planets as interactive elements that users can click on. There will be information pop-ups with detailed planetary data when the user's spaceship docks with a planet like Pluto. This includes images and detailed descriptions of characteristics such as orbital period and geological structure. Furthermore, users can customize their exploration paths and spaceship settings for a tailored experience.

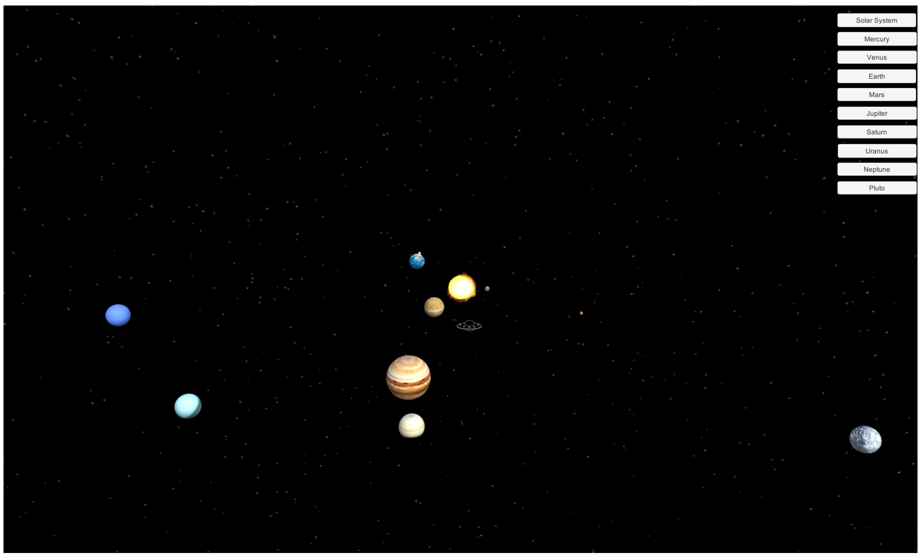


Fig. 6. Improved Solar System Interactive Visualization

4.4.1 ***Implementation of Processing platform.*** Processing is a popular programming language and environment for designers to create visual animations and interactive experiences. We initially chose to use Processing, which has an intuitive syntax for experimenting with the graphical application. The process begins by first establishing a 3D viewing environment on Processing and connecting to a serial port (e.g., "COM16") linked to the MPU6050 accelerometer and gyroscope. This enables continuous Processing of serial port data from the MPU6050 accelerometer and gyroscope on the JWST 3D model, where we can know the orientation and rotation angle of the model. The visual display is dynamically adjusted to depict the model's orientation, set against a dark background with enhanced lighting for a more significant visual impact. For example, when users move the 3D model to the right, the spaceship in the software will move respectively. When the users move the spaceship to view the size of the sun, the visual size of the sun increases, and the measurements will appear as text.

4.4.2 ***Limitation of using Processing.*** While Processing is suitable for rapid development and prototyping, it is inefficient, with complex simulations requiring high precision. Processing's 3D rendering capabilities are less advanced than those of engines like Unity or Unreal, limiting the potential for high-quality visuals. For example, Processing is more likely to struggle to maintain a smooth frame rate and can result in lags in animation. As we aim to simulate solar system dynamics with high precision and numerous interactive elements, this demands significant computational resources and time, which can exceed the capabilities of Processing.

4.5 Structural Observational Study 2

The objective of this study is to observe the type of interactions the participant has with the exhibit. The study is to verify further if the exhibit achieved our aim of increasing their knowledge and interest in cosmology.

4.5.1 ***Participants***. We invited 12 participants to our exhibition, all students aged 18-24 and the gender ratio was six males and six females. We let the first six people visit and use our device, fill in a pre-study questionnaire before that, and then fill in a post-study questionnaire after they attend the exhibition and make comparisons based on the two reports. Six other people were asked to visit and use only our website without the hardware part, and they were also asked to fill out the same two study questionnaires.

4.5.2 ***Procedure***. This study comprises 2 stages.

(1) Pre and post-study questionnaire to investigate the participants' change in interest and knowledge level after interacting with the exhibit
(2) Structural Observational study to observe the type of interactions that the participants have with the exhibit

- We set up our exhibit in a room where we projected the solar system projection onto the wall.
- We recruited participants from our social circle of friends.
- We invited participants to complete a pre-study questionnaire before leading them to the room to try our exhibit.
- We simulated a typical museum environment and gave no verbal instructions except asking participants to tell us when they finished the exhibit.

For the observational study, we noted down the various interactions that the participants had. Once the participants finished the exhibit, they informed us, and we noted the total time taken. We invited participants to fill in a post-study questionnaire. The aim was to provide feedback and gain insight into any changes in their interest and knowledge level from before the exhibit.

4.5.3 ***Questionnaire methodology***. To investigate the effectiveness of our exhibit, we compared the indicated knowledge and interest level of the participants by giving them a pre and post-study questionnaire. In the pre-study questionnaire, we asked participants two questions - about their current knowledge level and interest level in cosmology. We provided examples of cosmology, such as the solar system, telescopes, and galaxies.

In the post-study questionnaire, we asked participants the same two questions about their new knowledge and interest level in cosmology. Additionally, we asked them to fill out a Likert scale from 1-5 on their engagement level and whether the exhibit met their expectations. Lastly, we included an open-ended feedback section for them.

4.5.4 ***Questionnaire Results***. The results show that 66% of the participants benefited from our exhibit with increased knowledge and interest. There is a correlation whereby users who gained new knowledge also have an increase in interest in cosmology.

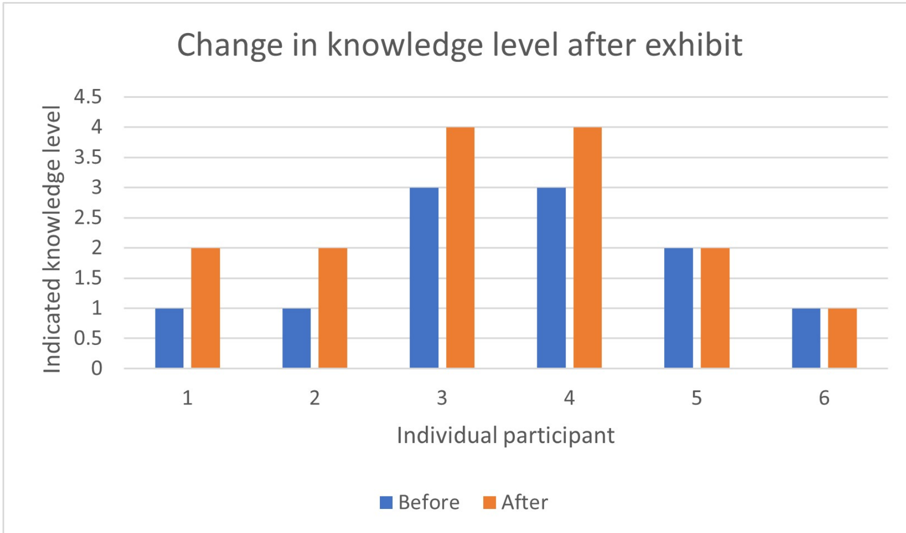


Fig. 7. 66% of the participants have an increase in knowledge after interaction with the exhibit

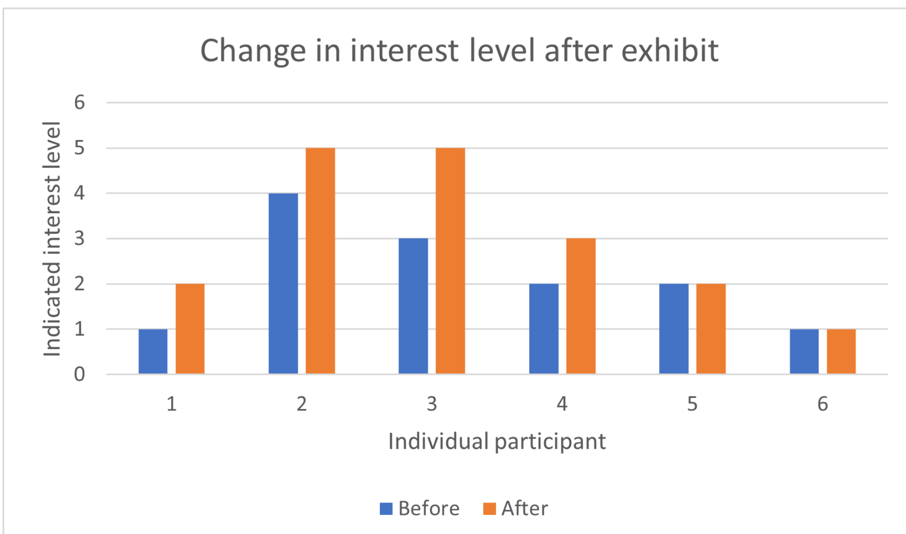


Fig. 8. 66% of the participants have an increase in interest after interaction with the exhibit

The average engagement level was three; only half of the participants were satisfied with the exhibit. Hence, this shows that our setup did not engage the participants as expected. Even in the change in interest level comparison, most participants only increased by 0 or 1 unit. To better understand the reasons behind this, their qualitative feedback can provide insights. First, 3/6 participants gave the feedback that the spaceship moved too fast and took some time to get used to the exhibit. Next, 2/6 participants said that having an instruction manual at the start would help give direction. Hence, this feedback was mainly on the user interface of our design, which we quickly changed by reducing the spaceship's speed and creating a PowerPoint beside the exhibit.

4.5.5 ***Questionnaire Thematic analysis.*** We conducted a thematic analysis of the feedback via open coding analysis by systematically reviewing the feedback from participants, identifying recurring themes of the feedback, and organizing them into meaningful categories. We identified the following categories: Overall experience, user interface difficulties, and desire for a task. The results showed that participants generally found the activity "engaging" and "fun", particularly praising the interactive element of moving the spaceship and the overall design aesthetics. However, there were challenges with controlling the spaceship as it was too fast and difficulty toggling on words as they were "too close together" or "too small". Additionally, users desired sound effects as they felt the experience to be "too quiet". Lastly, users initially expressed confusion and a desire for some tasks and introductions to provide a more guided experience. These findings highlight both strengths, such as engagement and visual appeal, and areas for improvement, such as better user interface, audio integration, and task clarity to enhance the overall user experience.

4.5.6 ***Structural Observational study.*** After observing 10 participants interacting with WebbSpace Explorer, we video-recorded their expressions of interest, curiosity, and musing (see Figure 4). Through qualitative analysis of the observed results, we draw the following conclusions (see Figure 5):

Serial Number	Participant ID	Observation Time	Interaction Content	Observer's Notes
1	001	10:00-10:15	Interaction with smart exhibit	Participant showed strong interest, frequently touched and asked questions about the exhibit.
2	002	10:20-10:30	Observing smart exhibit	Participant showed concentration, observed for a long time and occasionally took notes.
3	003	10:35-10:45	Attempted interaction with smart exhibit	Participant attempted to interact with the smart exhibit but encountered difficulties and gave up trying later.

Fig. 9. Example of partial reaction record

Interest: Regarding interest, we found that most participants (n=8 out of 10) showed strong interest, such as laughter or words of active participation. These participants actively experience the content and functions presented by WebbSpace Explorer through active participation and interaction. They were very interested in the information and technology presented and showed a highly positive attitude and commitment.

Curiosity: Regarding curiosity, a significant portion of participants (n=7 out of 10) showed notable curiosity. They may stay near the exhibits for a long time and carefully observe every detail, showing an attitude of exploration and discovery. This indicates that participants are curious about the new, unique, or unknown content of WebbSpace Explorer and are willing to actively explore and understand it. They displayed a strong desire to explore and be curious about it.

Contemplative: Although the proportion of responses was slightly lower, a portion of participants (n=4 out of 10) still showed a contemplative attitude. This indicates that participants may start to think about usage methods or content when interacting with or observing WebbSpace Explorer, showing active participation and in-depth thinking. They try to understand the information and ideas conveyed by WebbSpace Explorer, thus enriching their visiting experience and cognitive level.

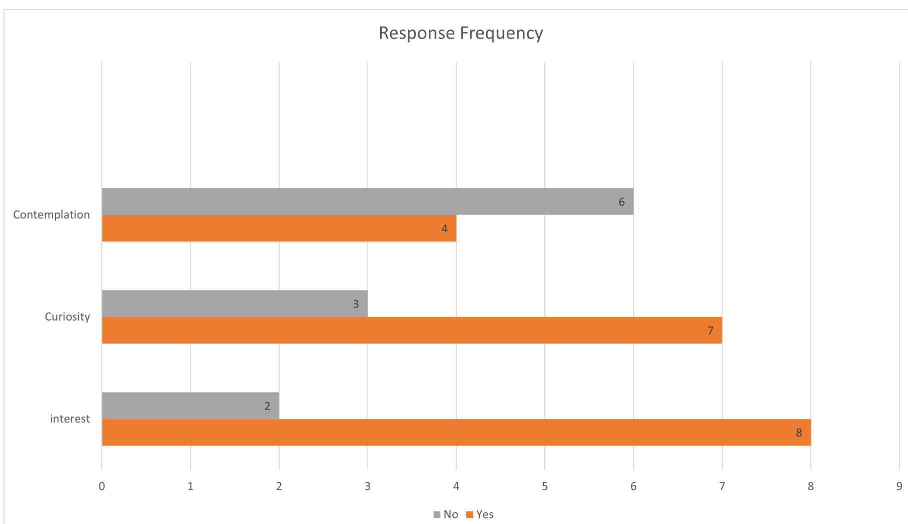


Fig. 10

Based on the above observations, we can conclude that WebbSpace Explorer successfully aroused participants' interest, curiosity, and thinking, prompting them to participate and explore actively. This further proves that this interactive method significantly enriches the museum visiting experience, attracts the audience's attention, and stimulates thinking. However, we are also aware that this study has certain limitations, such as the small sample size, which may affect the generalizability and reliability of the conclusions. Therefore, future research evaluations will compare the applicability of WebbSpace Explorer to different types of people to obtain a more comprehensive and accurate understanding.

4.6 Comparative study

This study evaluated the impact of two different interaction styles on knowledge acquisition. The experiment adopted a two-control group design to ensure the reliability and comparability of the results.

Control Group 1: 6 participants only used interactive websites to learn about the solar system.

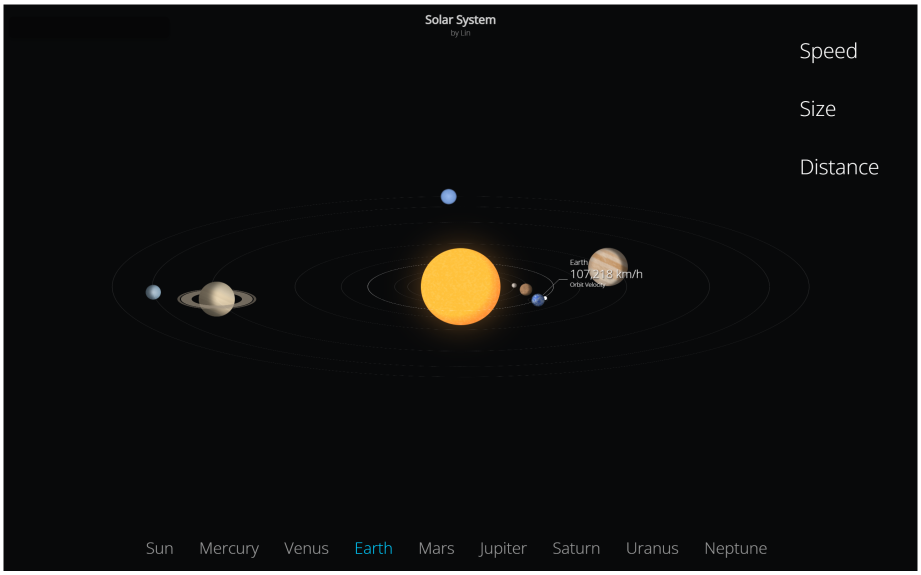


Fig. 11. Solar System website

Control Group 2: Also composed of 6 participants, but they learned about the solar system by interacting with JWST's 3D printed model and using the interactive website

Fig. 12. JWST's 3D printed model and the Solar System website

4.6.1 *Experiment procedure*

. **Learning tasks:** Participants are required to use designated learning tools (interactive websites or JWST's 3D printed models and interactive websites) to learn knowledge about the solar system, including planetary orbits, celestial body characteristics, solar system composition, etc.

Learning time recording: The time each participant spent using the learning tool was recorded during the experiment. The study time of participants in control groups one and two was compared and analyzed.

Knowledge Assessment: Participants completed a solar system knowledge questionnaire after completing the learning tasks. The questionnaire covered relevant knowledge about the solar system and was used to assess participants' knowledge.

4.6.2 *Experimental results*

. **Difference in learning time:** Participants in control group 2 spent an average of about 3 minutes using the product, while participants in control group 1 spent an average of about 1.5 minutes, indicating that users in control group 2 are more willing to spend more time learning tools. to interact.

Differences in knowledge acquisition: Participants in control group 2 showed higher accuracy in the solar system knowledge questionnaire. Among them, participants in control group 1 had an accuracy rate of approximately 60%, while participants in control group 2 had an accuracy rate of approximately 70%.

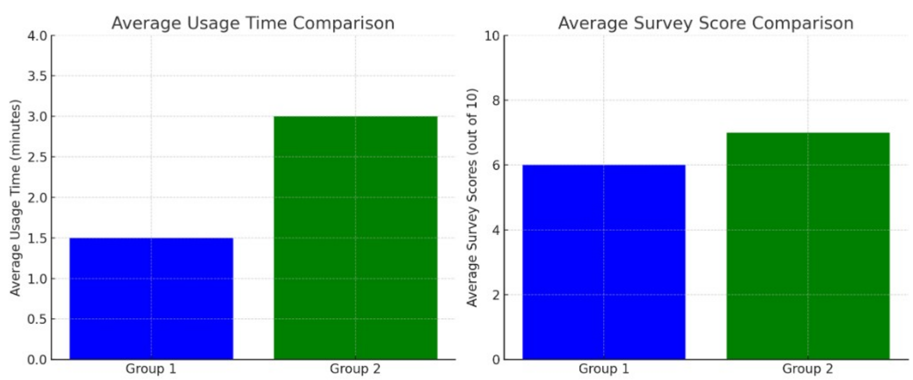


Fig. 13

4.6.3 ***Experimental results***. Through the analysis and comparison of experimental results, we found that using JWST's 3D printing model and interactive website to learn solar system knowledge interactively can improve users' learning time and knowledge acquisition ability more effectively than simply using interactive websites. In addition, participants in control group 2 showed greater learning interest and investment in interacting with the physical model, which may be one of the main reasons for their increased learning time and improved knowledge acquisition ability.

4.7 Software Design: Final Version

Although our initial design is shown to be engaging in study 2, we iterated the design to be more engaging in three ways. Instead of a static solar system image, we changed to an animated image where the planets constantly move. Second, we changed the user interactive features, such as slowing the spaceship's speed, making the words bigger and adding sounds to user interactions. Last, we introduced tasks via a PowerPoint presentation to motivate users to explore the solar system.

4.7.1 ***Overview of final design***. On the website, users can interact with texts representing the Sun, planets, and various descriptors such as 'Speed,' 'Size,' and 'Distance.' These interactive texts react when the virtual spaceship hovers over them, as follows:

- Position the spaceship above an interactive text for about 0.5 seconds.
- The action mimics a mouse click.
- Subsequently, the website displays additional information related to the selected element on the left side of the screen. This is accompanied by an audio output of a summary of this information, which allows an inclusive experience for visually impaired users.

The following figures provide visual examples of the website's interactive display:

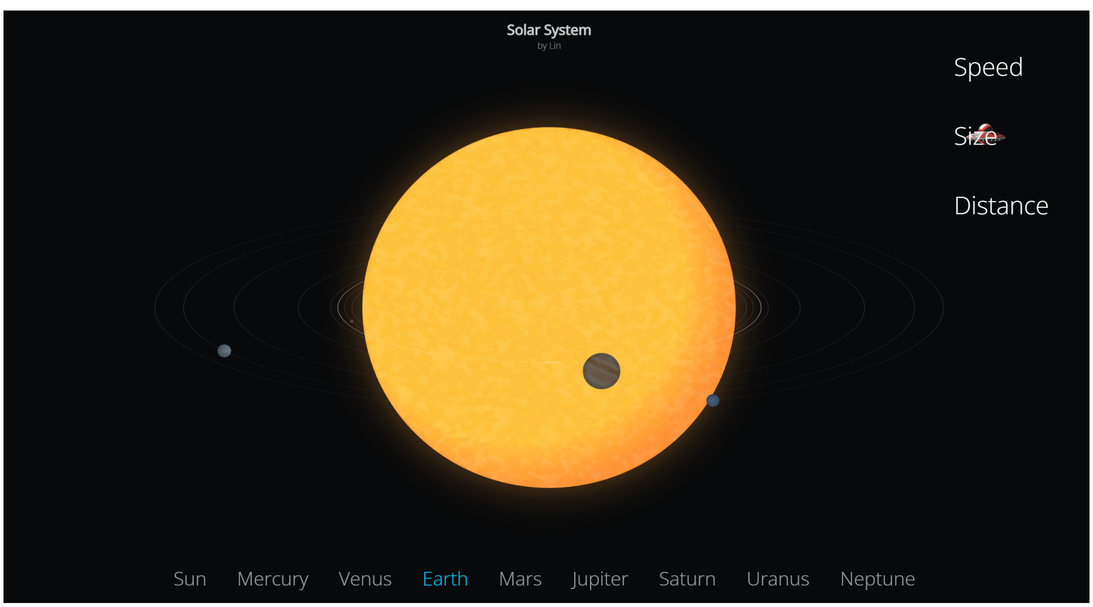


Fig. 14. Web interface when the spaceship hovers over the 'Size' option.

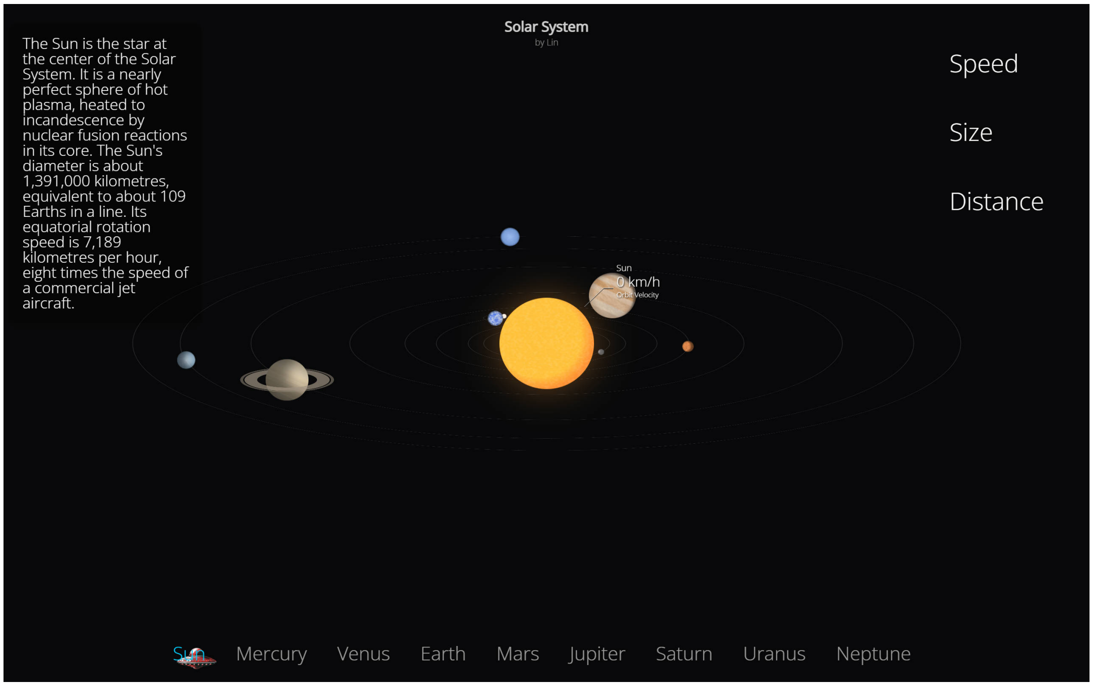


Fig. 15. Web interface with information pop up

4.7.2 ***Overview of implementation***.

- The MPU6050 on the 3D model records the gyroscope and accelerometer values, which can be read via a Serial Port on the computer.
- Using Web Serial API, the website establishes a connection with the serial port and fetches the motion data directly from the port. The values are not stored in the cloud for this project to reduce complexity.
- Using Javascript, the received gyroscope and accelerometer values are processed to update the spaceship's position.

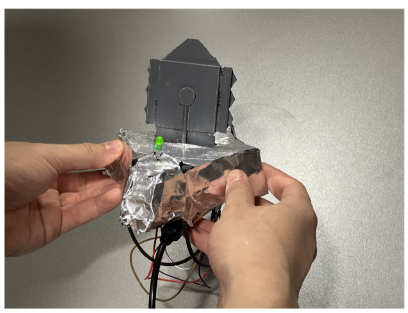
There are a few benefits of creating a website using JavaScript, CSS, and HTML and using direct Web Serial API over the previous processing platform:

- We reduced computational demands and associated costs by eliminating server-side processing.
- Standardized security measures are more accessible with a direct Web API approach.
- The direct Web API approach enhances system flexibility, facilitating integration with other platforms and technologies.
- The web interface is versatile as it is optimized for recent versions of popular web browsers, including Chrome, Firefox, and Edge.

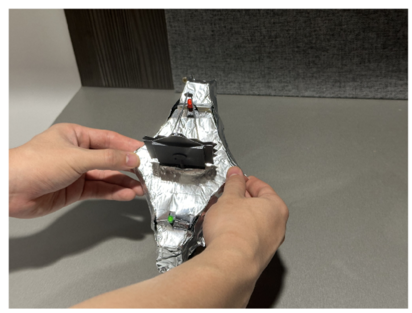
4.7.3 ***Website Implementation.*** The website is designed using Javascript, HTML and CSS. The 3D view of the website is achieved using CSS transformations and perspectives to create the illusion of depth and spatial relationships between the planets, moons, and the sun. The transform-style preserve-3d property is used to maintain the 3D positioning of elements. The static elements, such as planets, are styled with CSS to add box and border shadows to induce a 3D effect.

For the orbiting and rotating animations of the solar system, we used @keyframes in CSS. @keyframes is a CSS at-rule which specifies property values at different timestamps for a smooth animation sequence.

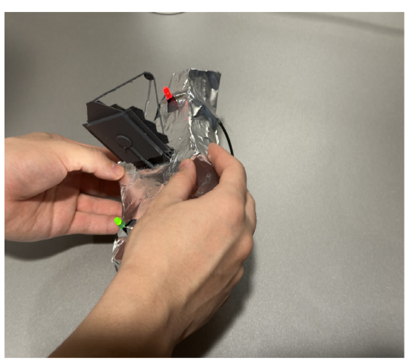
4.7.4 ***Tilting the prototype.*** This section provides detailed instructions on interacting with a virtual spaceship on a web interface using a gyroscope controlled via an Arduino Uno. When using this prototype, ensure the gyroscope is placed on a stable and level surface to detect movements accurately. The gyroscope's movements are mirrored by the spaceship on the website, allowing the user to engage with elements representing celestial bodies and various astronomical properties. When we move JWST's 3D-printed model forward, the spaceship will move upward, and when we move it backwards, the spaceship will move Down. When we move it to the left, the spaceship will move to the left. When we move it to the right, the spaceship will move to the right. The gyroscope detects tilt and rotation, translating these physical movements into navigational commands for the virtual spaceship. The movements are categorized into four directions, as depicted in the figures below:



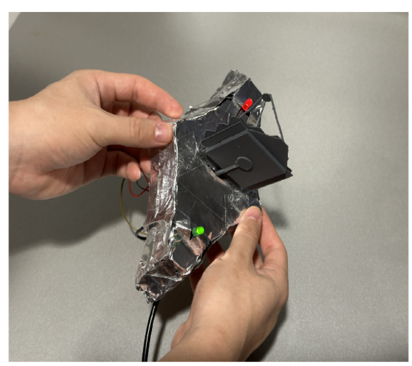
(a) **Moving up**



(b) **Moving down**



(c) **Moving left**



(d) **Moving right**

Fig. 16. Four directional movements

5 DISCUSSION

The main finding of this study is that by combining gyroscope technology and interactive website functionality, the "WebbSpace Explorer" platform we developed significantly enhances the user's learning experience. Compared with traditional education methods, the learning outcomes of platform users have improved by approximately 10%. The platform's multi-sensory interactive design and dynamic interactive features attract users' attention and increase users' participation time (about 1.5 minutes longer than just showing the website), indicating that users are more inclined to interact and explore with the platform. These findings highlight the ability of our products to stimulate user interest and increase product usage time compared to traditional display methods by introducing multi-sensory interactive products. Specifically, we measured user learning outcomes through a pre-and post-questionnaire that included questions to assess users' understanding of and interest in cosmological knowledge. The results show that 66% of users have improved their knowledge and interest after participating in the "WebbSpace Explorer" experience. In addition, we recorded the total time users spent interacting with the display. We compared it with traditional methods and found that users using "WebbSpace Explorer" had a longer average engagement time, verified through field observations and time recordings. These interactive features improve users' learning and increase their engagement and satisfaction, thereby confirming the effectiveness and appeal of our products.

Compared to the existing literature, the results of this study are consistent with previous research on the effectiveness of interactive devices in museum exhibitions, which has shown that interactive technologies can enhance visitor learning and engagement. However, compared with the limitations of VR and AR technology in achieving direct interaction, as mentioned in some literature, our platform provides more in-depth educational interaction through direct physical interaction and enhanced sensory experience.

The significance of the research is that the new interactive education platform "WebbSpace Explorer" provides users with an unprecedented learning experience and demonstrates through empirical research the potential impact of this platform on improving the public's interest in and understanding of astronomy (Interactive Device). From a practical application perspective, these results indicate that interactive exhibitions improved with modern technologies can effectively enhance the attractiveness and accessibility of educational content, especially in science education and public engagement.

While considering several enhancements to the "WebbSpace Explorer," we evaluated the possibility of integrating an AI chat assistant into a 3D-printed replica. This function aims to improve the interactive experience with physical prototypes and achieve customized audio output through AI. However, we ultimately decided not to adopt this feature due to the following considerations: First, integrating AI assistants requires a lot of development and ongoing maintenance resources, and achieving real-time and accurate interaction with educational content presents significant technical challenges. To ensure the stability and reliability of the user experience, adding such a complex system may bring potential instability and errors. Second, our core goal is to enhance the learning experience through physical interaction and sensory feedback. The simple design encourages users to learn and explore through touch, vision, and hearing. At the same time, integrated AI may distract users from physical interactions and reduce the immersive learning experience. Finally, from a cost-benefit perspective, the additional hardware modifications, software licenses and ongoing support required by the AI system are more expensive. With the above factors in mind, we focused on optimizing the core interactive and educational features of WebbSpace Explorer. Furthermore, there is no option for an integrated chat assistant.

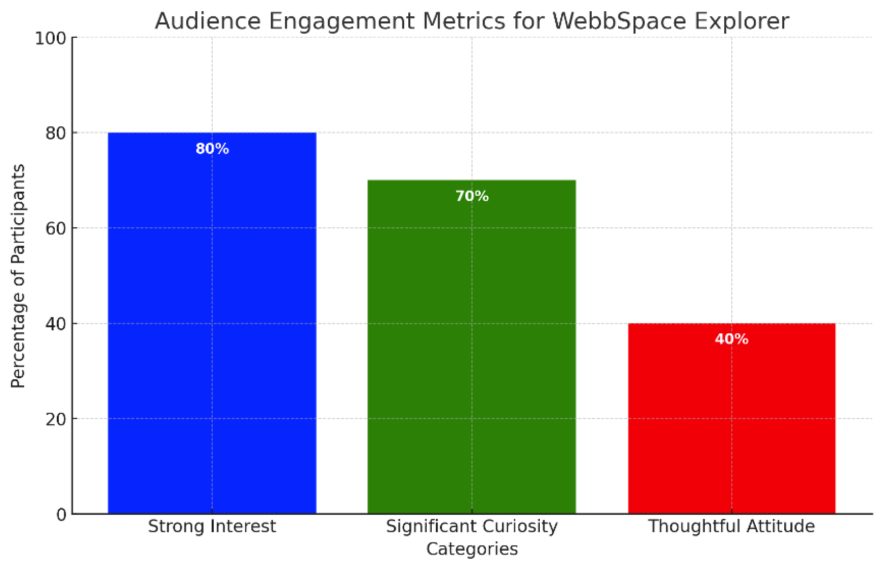


Fig. 17. Users are engaged with Webbspace Explorer

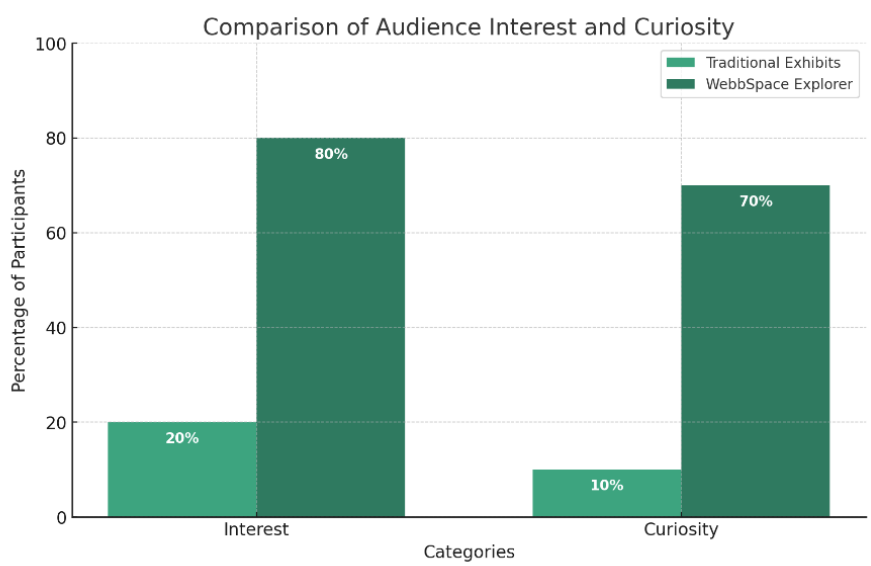


Fig. 18. Engagement of Webbspace explorer vs traditional exhibit

The WebbSpace Explorer provides proof of concept for providing an engaging experience. The findings have several limitations. Our model and the website can be easily modified to include different bits of knowledge, audio output or different 3D models. However, our findings have several limitations. The age demographics of the participants for Study 2 are only 18-24, which provides a narrow understanding of the user-friendliness of WebbSpace Explorer. This study also does not investigate the numerous possible interactive elements, such as the suitable size of the 3D model, the preferred audio output or specific knowledge content. Furthermore, the WebbSpace Explorer is limited in providing knowledge about the JWST itself.

6 FUTURE WORK

In future endeavours, it is envisioned that advancements will be made in augmenting the interactivity, educational efficacy, and user engagement facets of the "WebbSpace Explorer" project, thereby fostering a more immersive and profound space exploration encounter for visitors. Specifically, the focus will be directed towards refining the following domains:

Introducing artificial intelligence voice question and answer: The landscape based on artificial intelligence in museums is developing rapidly, including chatbots for participation, predictive analysis for attendance, sentiment analysis for visitor comments [10] and integrating the artificial intelligence voice question and answer system into the "WebbSpace Explorer" platform. This feature enables visitors to interact with virtual tour guides in real time, ask questions, and receive detailed answers, further deepening their understanding of space exploration and astronomy knowledge.

Adding more interactive features: Besides the existing gyroscope technology, we are introducing more interactive features, such as touch sensing or interactive buttons, enabling visitors to explore exhibits in more aspects and interact more directly with the platform, enhancing their sense of engagement and learning.

Expanding educational content: To cover more astronomical knowledge and exploration topics. Through continuously updated and enriched educational content, it would be possible to attract more visitors and provide a more comprehensive and in-depth learning experience.

How to improve the current prototype: To improve the structure of the current Webb Space Explorer's structure to better fit in a museum environment, here is what we could do:

The exterior of the 3D printed parts is printed with metal materials to ensure the device's reliability and that it is not easily damaged. At the same time, the current wired technology can be modified into wireless technology to achieve farther and freer control. Finally, a slot can be designed inside the 3D printing for storage, making Arduino-related hardware ensure that no wires are exposed. Finally, a device like a camera pan-tilt is used to fix the bottom of the device to ensure that all movements comply with the requirements to ensure the safety and reusability of the device.

User experience optimization: Adding user experience optimization would enable developers to improve the interactive website dynamically and optimize the platform based on their opinions and suggestions. We can continuously optimize the user interface and interaction design to improve visitor satisfaction and participation, achieving better educational and experience effects.

7 CONCLUSION

Through the "WebbSpace Explorer" project, this study verified the significant effectiveness of the interactive education platform in improving learning effects (increased by 10%) and increasing engagement (users stay about 1.5 minutes longer than ordinary products). We successfully blended gyroscope technology with an interactive website to provide users with a simulated space exploration experience. This innovative educational approach inspires users to learn and expands their knowledge of the solar system.

In the future, This project can enhance the platform’s interactivity and attract user participation by introducing a voice question-and-answer system supported by artificial intelligence. At the same time, by expanding the educational content, it is not limited to the solar system to cover a broader range of astronomy topics. In addition, through more communication with users, the user interface and interactive design are optimized to continuously improve user satisfaction and educational effectiveness. With these improvements, we hope to make WebbSpace Explorer a more comprehensive and engaging learning and experience tool.

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9 APPENDIX

9.1 Teamwork Diversity and Inclusivity

Our diverse team, which consists of Kitan Wang, Jingbo Yuan, Carina Chu, RuiJun Li, and Linfeng Cai, understands the critical value of inclusivity and combining a range of viewpoints and skills to accomplish project goals. Our multicultural backgrounds, as well as our diverse academic interests and technical skills, inform our approach to diversity, which improves teamwork and enhances project outcomes.

9.1.1 ***Diverse Skills and Role Allocation.*** To capitalize on their talents and areas of expertise, each team member was given a specific section of the report to complete:

Jingbo Yuan

- Responsible for the first draft of the Abstract, Introduction, Structural Observational Study, Comparative Study, and Future Work.
- Added relevant citations and links to the Introduction to improve the readability of the paper.
- Participated in video filming.

Kitan Wang

- Completely covered and accurately cited the Related Work, References, and Appendix sections.

Carina Chu

- Co-responsible with Jingbo Yuan for the first draft of the Introduction, Structural Observational Study, Comparative Study, and Future Work.
- Collaborated with Linfeng Cai to complete the Design and Implementation sections, ensuring that the paper's content was consistent with the core of the product design and supplemented with relevant experimental setups and data analysis.

Linfeng Cai

- Completed comprehensive product design, including hardware and software integration, website design, and selection of appropriate 3D models.
- Engaged in multiple product iterations through frequent user interactions to enhance product usability and user experience.
- Reviewed and revised the Abstract, Introduction, Related Work, Design and Implementation, Discussion, and Future Work sections to ensure the accuracy of the paper and maintain strong relevance between the paper content and the product.
- Finished the video filming.

Ruijun Li

- Selected appropriate hardware products and printed 3D models.
- Designed the initial drafts of the Hardware Design and Discussion sections.

9.1.2 ***Adaptive Communication and Inclusivity.*** We made inclusivity a priority by using flexible communication techniques. We accommodated different time zones and work schedules by sharing updates and feedback asynchronously through the use of online tools like Slack and Google Docs. Weekly meetings that were arranged at times that worked for both parties were essential for reviewing progress, settling problems, and assigning tasks. Every team member's voice was heard and respected thanks to these meetings.

9.1.3 Collaboration and Problem-Solving. Our project's difficulties included integrating different project components and disparities in data interpretation. Through the appreciation of varied viewpoints and the utilization of a methodical approach to issue resolution, we produced inventive resolutions. For example, when Study 2's results were inconclusive, Carina and Jingbo held a thorough analysis session and used Kitan and Lin's insights to reevaluate and improve our procedures. In addition to resolving the problems, this collaborative approach improves the quality of our reporting

9.1.4 Conclusion. We completed the thesis and corresponding academic requirements through regular internal communication and many discussions with TAs.

9.2 Video link

Click here to watch the video: Webb Space Explorer