Enhancing Accessibility through 3D Models in Museums

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Abstract

The barrier of accessibility presents itself as a major difficulty when individuals with disabilities attempt to access cultural heritage and educational resources stored in museums. The research examines how modern 3D modeling technologies deliver increased accessibility opportunities to museum structures. Digital replicas when combined with tactile experiences through 3D models enable persons with visual impairments along with those who have mobility issues and cognitive disabilities to gain access to museum exhibits. The research analyzes existing applications along with technical progress and projected advances regarding 3D model integration in museum displays to construct open access spaces. The article delivers extensive discussion about ethical implications and museum-wide access problems alongside interdisciplinary partnership opportunities which boost museum accessibility across the globe.

Keywords: Accessibility, Tactile, 3D Models, Museums, Cultural Heritage, Inclusive Design, Digital Innovation

Introduction:

The combination of using 3D models and interactive exhibitions is helpful since every visitor has an opportunity to interact physically with the artifact, which makes museums accessible to everyone. Many of them are a substitute for the movement, providing the opportunity to touch the artifacts for the representatives of the visually impaired people. On the same note, 3D scanning and printing allow reproductions of various artifacts, and their fragile state or being situated in locations that the broader audience cannot access. Museum is an essential element of the community through which cultural and educational values for the most significant number of people can be valued. The established ways of museum displays create accessibility barriers for disabled persons, which consequently reduces their cultural artifact interactions. In order to overcome these challenges, the use of 3D modeling and the incorporation of interactive exhibitions have proved to be an effective way of improving inclusiveness in museums. 3D modeling can be used to create exact replicas of the artifacts in both virtual and physical forms, whereby persons with impaired vision can have an attempt at touching. On the same note, interactive exhibitions take advantage of telecommunication appliances like virtual realism,

augmented realism, and haptic perception with displays to enhance the experience palettes for audiences. These enablements also expand the spectrum of ways in which to engage with the displays and artifacts introduced in these spaces for an enhanced and interactive learning experience. The use of 3D modeling and interactive exhibits in the museums is seen as a step into a different level of museums that are more diversified with the use of technological tools. This paper aims to discuss these advancements and their effects on accessibility in terms of various applications and case studies, as well as technological enhancements and possible trends related to museums. These developments should be adopted by museums as a means of enhancing equal representation for all users.

Background and Literature Review

Methodology:

Making museum experiences engaging with 3D models and interactive exhibitions demands a systematic approach to the process, which combines the aspects of inclusive design, technology, and user-focused solutions. This approach will guarantee access by visitors with disabilities especially the visually impaired to enjoy the exhibits at the museums. The initial process involved in this is carrying out accessibility assessment to determine obstacles that can restrict the interaction of disabled visitors. This would entail conducting an accessibility audit and speaking with persons with varying needs so that they can be able to assure that the museum setting is accommodating. As pointed out in the paper by Ann Sawyer and Keith Bright (2014), a proper accessibility plan should start with the analysis of the current problems and engage the disability advocacy groups to come up with the knowledgeable solutions. After the assessment, 3D modeling technologies are essential towards making exhibits more accommodating. With 3D scanning, museums will be able to produce electronic copies of artifacts, which can be made into feelable models to be used by the visually impaired visitors. This has already shown success at the Violin Museum in Cremona, Italy where a 3D-printed copy of a Stradivarius violin allows visitors to touch and feel the instrument (Baskakova, 2019). These applications can be justified by the research article by Ballarin, M., Balletti, C. and Vernier, P. (2018) on 3D Printing to Museums and Cultural Heritage, where it is stated that the use of 3D can help bridge the physical inaccessibility and cultural engagement.

After the creation of the digital models, tactile displays are created by 3D printing or another fabrication technique. Through these exhibits, the blind and low-sighted visitors are able to touch the objects to learn more about historical artifacts. In The Power of Touch: Handling Objects in Museum and Heritage Contexts,

Elizabeth Pye (2007) explains that the value of touch experiences makes a visitor more connected to exhibits and other objects in the museum. The use of tactile maps and models has been pioneered by museums like the Museo Tiflologico in Madrid and here blind visitors can feel their way (Mesquita, 2021; Montusiewicz et al., 2022). To increase the accessibility, the use of audio guides, augmented reality (AR), and virtual reality (VR) in addition to the tactile models is possible. Museums may incorporate touch responsive screens where they can have auditory descriptions of the artifacts when they are interacted with by the visitors. Studies conducted by Kenderdine, S., and Shaw, J. (2014) indicate that AR and VR applications should be used to develop immersive experiences to disabled visitors and make cultural institutions more inclusive.

To make such innovations effective, user testing and feedback is necessary. The disabled should be involved in the testing stage to provide an opportunity to test the accessibility of 3D models and interactive technologies. Museums, prejudice and the reframing of difference by Sandell, R. (2007) confirms that visitor feedback is essential to the enhancement of the accessibility program as it is an immediate source of information about the experiences of users and their usability issues. Besides, visitor education and staff training are critical factors in the success of accessible exhibits. Museum staff must be trained to assist visitors with disabilities and educate them on how to use the new tactile and interactive features. In Including museums: Perspectives on museums, galleries and social inclusion by Dodd and Sandell (2001), the authors stress that an inclusive museum environment depends not only on technology but also on an informed and empathetic staff.

Lastly, there is a need to have constant assessment and advancement to ensure an inclusive museum experience. Regular evaluation and updating depending on the feedback of the visitors make accessibility measures effective and correspond to the evolution of technologies. Transforming museums in the twenty-first century by Black (2012) states that those institutions, that implement constant accessibility enhancements, become leaders in choosing to be inclusive in their cultural involvement.

Through this approach, museums would be able to develop interactive and approachable experiences to visitors. Combining 3D modeling, tactile displays, and interactive technologies make cultural heritage more inclusive so that people with disabilities can access them.

Research Method

Tactile 3D Models for the Visually Impaired

The tactile approach within museums creates 3D models, which aid in the educational development of people with visual impairments. Visitors can easily experience such models through sculptures and 3D printers to use as teaching materials to enhance tactile learning. This is done through the guidelines that point to available educational resources and explain the effective printing of models as well as strategies for use. The availability of educational materials and increased accessibility are a result of the tactile 3D models that support the needs of blind and visual impaired individuals. Visual information transforms into physical forms through these models, which create better comprehension of difficult ideas and spatial structures together with abstract concepts. which is clearly visible, for example, but not limited to the "Touch the Universe" exhibit implemented by the JAPAN Science Museum Association network (Usuda-Sato, et al, 2022).

Fig (1) shows on top: The Mars (left) and the Moon (right) spherical tactile models developed by A Touch of the Universe and re-created by NAOJ using its downloadable STL files. On bottom: The tactile scale model of the planets created initially as Universe in a Box educational kit and modified by the authors. A transparent bag enables BVI people to touch a small planet ball with a braille label without losing it (Usuda-Sato, et al, 2022, fig. 3)

Different museums have used touchable 3D models to develop the exhibition spaces that are inclusive to all. Replicas of artifacts, in addition to sculpture and architecture, are purposely crafted to be touched by visitors with visual impairments as a way of giving them a good experience of accessing cultural heritage.

Fig (2) shows a tactile busts in bronze, terracotta, marble and wood in the Sculpture Discovery Space (Communiqué de presse, 2023 @ Musée du Louvre, Raphaël Chipault; Public Domain: https://presse.louvre.fr/lespace-de-decouverte-de-la-sculpture/)

Blind people can also use tactile maps and physical models since they will be navigating through some difficult environments. The spatial comprehension is improved by the physical quality of such assistive devices, which facilitates the independent movement patterns (Auricchio, 2017). The creation of portable tactile maps was also addressed with the help of the research that was aimed at assisting people with visual impairments in their orientation and mobility exercises (Voženílek, 2014).

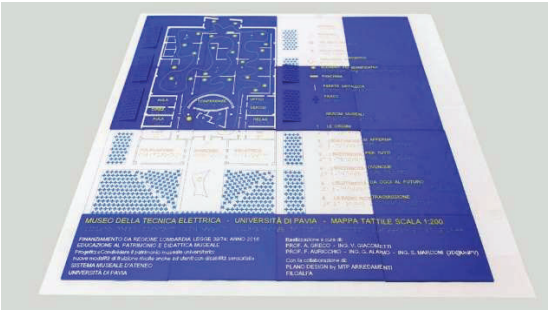

Fig (3) shows a tactile map of the MTE museum in pavia (Auricchio, 2017; Public Domain:

http://www-4.unipv.it/3d/research-activities/tactile-map-3d-printing-visual-impaired/)

Tactile 3D models are driven by the technology of 3D printing, which is based on creating 3D objects from computer 3D models (Voženílek, et al, 2009), and they constitute essential educational tools not only in museums but also for teaching, such as geometry and both biology and geography subject (Guidelines, 2010). As well as the anatomy models, they enable students to discover the human body with their hands, which serves as a different approach from visual diagrams (Hoffmann, 2020). Educational topographical maps created via 3D printing systems allow individuals to sense geographical features; thus, they develop better spatial understanding (Gill, 1973).

Fig (4) shows a textured topographic map of the state, Utah Natural History Museum @ Blue Rhino Studio, 3277 Sun Drive, Eagan, MN, 55121 | 651.287.0900; (Public Domain: https://www.rhinocentral.com/utah-natural-history-museum-topographic-map/zbf5nz3jdmagepx7vaza1qnljkngdx)

Interactive 3D Maps and Navigation Tools

These days, interactive 3D maps and navigation tools are now an indispensable instrument to improve the experience of visitors in a museum, as they serve as dynamic and immersive ways to navigate exhibits and to navigate through an overly complicated layout (Singh, et al, 2023). Not only do these technological advances help with locating better, but they also help cultural content to be made available to audiences with all kinds of issues, such as visual impairments. Among the most prominent examples of the applied interactive 3D mapping in museums is the work of Living Map and The Metropolitan Museum of Art (The Met), New York City. Real-time positioning and routing were a few features that they developed as an

indoor digital mapping and wayfinding solution in Living Map. Extensive efforts have been made to make these enhancements to the visitor experience, and they have significantly improved the visitor experience due to accessible routes and live navigation assistance allowing visitors to easily locate the exhibits and amenities within the large museum space.

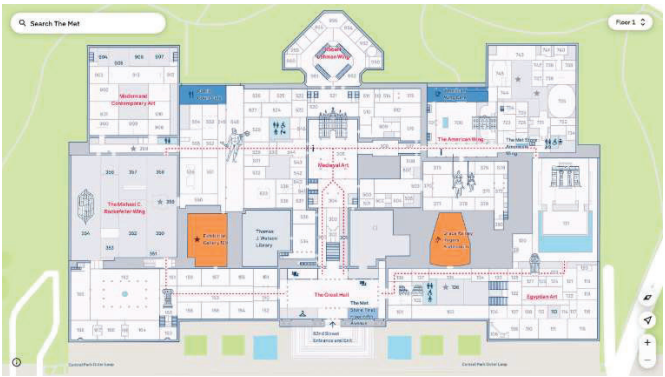

Fig (5) Living Map with a digital indoor mapping and wayfinding tool for museum visitors (Public Domain: https://maps.metmuseum.org/?floor=1&lang=en-GB#17/40.779448/-73.963517/-61)

The project of Bento Museum, which addresses the needs of visually impaired visitors, is an innovative solution in addition to its 3D and complex interactive museum maps. By physically exploring tactile representations of museum layouts and accessed via a connected application, interactive labels that, when tapped, describe the 3D virtual museum layouts via audio, this is a design for users to explore. Independent navigation and museum experience improvement of blind or low-vision individuals can be made possible due to such multisensory engagement (Wang, et al, 2022).

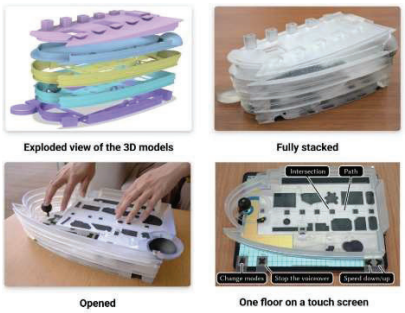

Fig (6) shows 3D data and models are available at (Public Domain: https://xiyue-w.github.io/projects/BentoMuseum/)

Fig (7) shows designs for different types of information inside Bento Museum (Wang, et al, 2022).

Along with this, the Royal Ontario Museum (ROM) has created interactive and responsive virtual museum tours to deal with challenges of accessibility. The tours come with an interactive map available from any location in the tour, through which people are able to see a complete layout of the exhibition with the possibility of going directly to selected exhibits. This method not only makes it easier to view the space when visiting for remote reasons but also is an alternative way for people with physical or mental impairments to become more involved in the artwork.

Fig (8) shows an online map, which allows you to choose the collections of the required country, available at (Public Domain: https://collections.rom.on.ca/search/*/objects/map)

Virtual Reality (VR) and Augmented Reality (AR) Experiences

Virtual Reality (VR) and Augmented Reality (AR) are changing the prospect of how visitors experience museums, providing a very interesting and interactive way for museum visitors to meet and interact with the cultural heritage. These

technologies offer museums an opportunity to overcome the limitations of traditional exhibition and offer dynamic and personalized experiences of the museum that serve a wide range of people. To advance the cause, museums are increasingly picking up on the sophisticated VR and immersive technologies to captivate the audiences. Indeed, the national museum of Australia exhibition in Pompeii attempts to recreate an eruption of mount vesuvius after every 15 minutes so that people can appreciate history at a visceral level. Arriving at Pompeii is an extraordinary new multisensory immersive experience of the volcanic eruption using a spectacular 360-degree recreation of the event and more than 90 items from the ancient city.

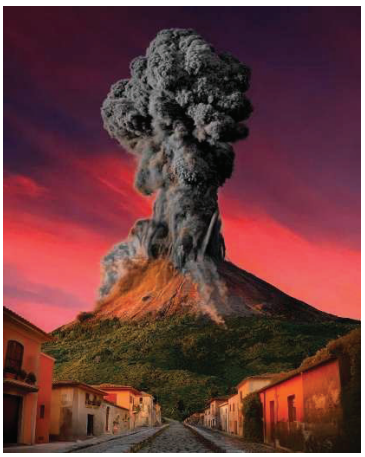

Fig (9) shows a shot from the VR of step inside Pompeii and discover life in the ancient city before the fateful eruption of Mount Vesuvius almost 2,000 years ago, (Public Domain: http://nma.gov.au/exhibitions/pompeii)

Besides livening up the visitor's experience, these types of immersive experiences make an educational point in that they bring to life historical events.

The Palace Museum in Beijing deliver better user interaction by using VR and AR technologies. The museum gives remote visitors multiple ways to experience its cultural collections by using digital platforms with AR and VR technology. The digital platforms let people explore three-dimensional copies of museum spaces and items to access cultural education without boundaries.

Fig (10) Shows a virtual tour of the Palace Museum. (Li, Wenhua, 2021; Public Domain: https://artsandculture.google.com/project/treasures-of-the-palace-museum; https://www.madhattertech.ca/chatter/virtual-reality-prized-beijings-palace-museum-forbidden-city)

The VR headset or your phone can be used to explore and walk around some sections of the Forbidden City and read exhibits as you observe the artwork lining the halls.

Online 3D Virtual Tours

Through their online 3D virtual tours, museums open their collections to all users worldwide, including people who cannot travel to the venue. You can see and touch these digital tours, offered by some platforms, in order to create a kind of remote engagement and interaction.

CGWorks created effective 3D displays of B&E Goulandris Athens Museum exhibits that users can explore and hear about through detailed audio content. One of the notable examples is that the CGWorks and Basil & Elise Goulandris Museum use their Athens partnership to show modern technology. CGWorks came up with an interactive 3D museum package that would feature the Basil and Elise Goulandris Museum of Athens in their digital systems. The tour displayed 3D exhibits on large screens connected to detailed text information that played voice recordings. CGWorks helps increase global audiences for the Basil & Elise Goulandris Museum through online exhibitions that anyone can view.

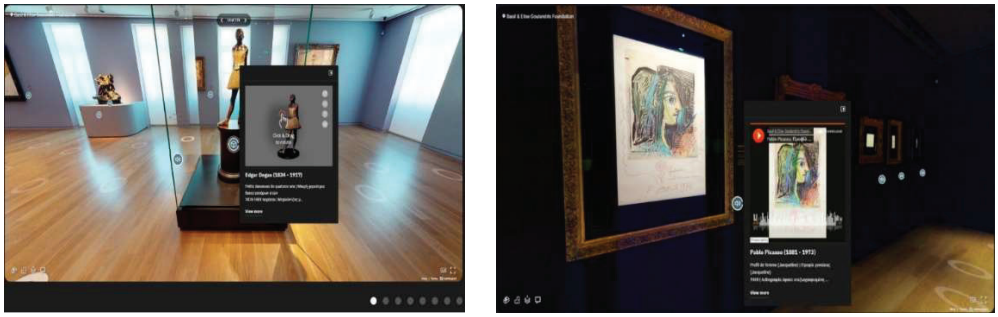

Fig (11) shows one of the creative design assets, a virtual tour including the audio factor, (Public Domain: https://www.cgworks.com/projects/basil-elise-goulandris-museum)

During 2020 COVID-19 struck hard as museums all across the earth needed to adjust to new operational modes. Museum closures throughout 2020 caused leaders to find alternate ways to share knowledge with their audience base and broader audiences. Why should cultural and historical institutions work towards access improvements during normal procedures when they can do this without a global emergency? In the case of the McFaddin-Ward House Museum (1), the virtual tour option was to construct a virtual tour system, which was to be developed after the pandemic.

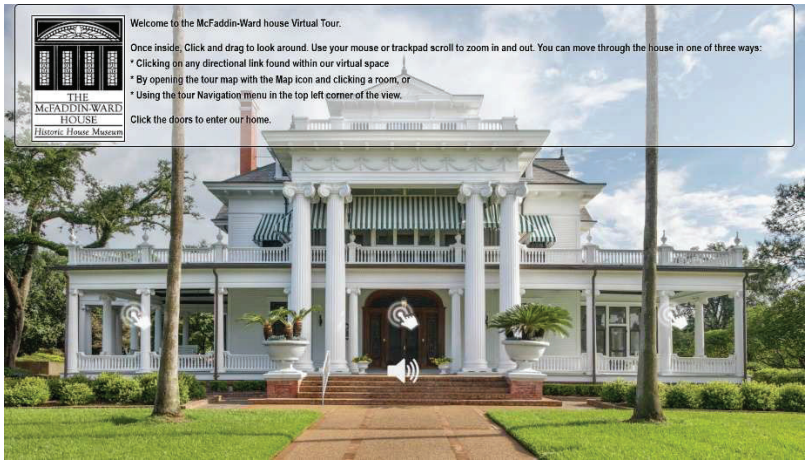

Fig (12) shows the main webpage of the museum, accompanied by the User Navigation Protocol for the McFaddin-Ward House Virtual Tour Interface, (Public Domain: https://www.mcfaddin-ward.org/tour/tour-general.php)

The virtual tour uses CatalogIt (2) to display extensive details about the home, its history, and its objects.

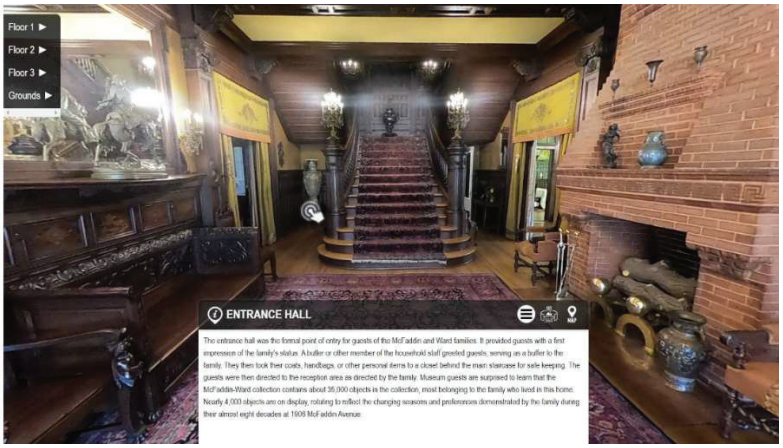

Fig (13) shows an interpretive visualization of the entrance hall in a historic McFaddin-Ward House Museum virtual environment, (Public Domain: https://www.mcfaddin-ward.org/tour/tour-general.php)

Results and Discussion

The findings of this paper suggest that the introduction of 3D modeling technologies can significantly enhance the level of accessibility in museum settings, especially to visitors with visual disabilities. Tactile 3D replicas convert the traditionally visual exhibits to multisensory experiences and allow users to react on objects by touch and spatial awareness. This method improves cognitive concepts and facilitates the creation of mental images of objects that would otherwise not be available. The implementations conducted in Violin Museum, and others prove that the correctly recreated 3D models have the capacity to transfer form, as well as scale and texture and thus create intellectual understanding and emotional involvement. Moreover, the tactile maps and spatial models serve as the elements that help to increase visitor autonomy through enhancing orientation and navigation in the museum areas. The interaction between the user and these tools demonstrates higher levels of confidence and independence, which proves that the accessibility interventions with the help of 3D technologies are not limited to the interpretation of the exhibit but affect the visitor overall experience.

The results further demonstrate that interactive technologies, such as the use of augmented reality (AR), virtual reality (VR), and audio-integrated systems, are important complementary factors in increasing the accessibility. These technologies offer other sensory channels that meet the needs of various visitors and, in this way, are able to engage with cultural content in a less exclusive way. As an example, immersive VR applications being used in the establishment like the National

Museum of Australia have shown the possibility of recreations of environment and events that cannot be physically or conservatively accessed. This does not only enhance the engagement of the user, but also better knowledge retention where learning takes place in an interactive environment. Meanwhile, AR systems can be used to enhance the physical displays with more layers of meaning and to facilitate the personalized learning experience. The findings, however, also indicate that it is important to be careful when designing the interface because overly complex systems can result in the cognitive overload, especially among users with sensory sensitivities or low technological familiarity. This highlights the need to develop interactive museum technologies by considering the principles of user-centered design.

The development of online 3D virtual tours has become a prominent consequence of enhancing the accessibility across the tangible limits of museums. Digital programs, including the programs created by Basil and Elise Goulandris Museum, show how the virtual space can be enhanced with 3D visualization, spoken narration, and text, and provide an all-inclusive remote experience. The platforms allow more people to be reached especially to those getting hindered due to mobility or those who cannot travel. The COVID-19 pandemic has positively influenced the implementation of such technologies and proved their worth in the long term as a necessary tool to access it instead of a quick fix. In addition, virtual tours will enable people to become familiar with museum layouts and displays before they visit, which will make them less anxious and more confident when visiting the museum. However, the result also indicates the ongoing struggle with the issue of the digital divide, given that the differences in access to technology and different degrees of digital literacy can pose a limitation to the effectiveness of these solutions to some of the user groups.

One of the most important consequences of this study is the understanding that accessibility initiatives rely on user testing and feedback to be a success. The consultation of individuals with disabilities during the design and evaluation process results in more efficient and convenient solutions. The findings demonstrate that the usability and relevance of the 3D models and interactive systems are greatly improved through iterative user input improvements. Participants also stressed the use of correct tactile detail, intuitive navigation, and understandable and synchronized audio descriptions. These observations show that access would not be realized by technological innovation but significant and sustained working with end users. The integration of a feedback system into the development cycle can also ensure that accessibility features are responsive to the actual needs and changing expectations of the users, thus making them more long-term effective.

Another important factor emphasized is the support by the institution, especially in the aspect of training the staff and the visitors. Museums that invest in educating their personnel to operate with accessibility technologies and support visitors with various needs say that their results become much better in visitor satisfaction and inclusivity in general. Employees will serve as techno-mediators between the technology and the visitor with advice, historical background, and emotional assistance as needed. This aspect of human beings is vital in ensuring that a system of technology is used efficiently and visitors feel at home and comfortable. The results indicate that the accessibility is to be considered as a technical and social practice and a holistic approach is needed, which involves innovation, empathy, and professional competence.

Although the identified impacts are positive, the study unveils some challenges that can be an obstacle to the adoption of the 3D accessibility solutions on a large scale. The biggest obstacle is the financial aspect since the creation of high quality 3D models, immersive technologies and development of digital platforms needs major investment. Moreover, technical constraints, such as problems with the sustainability of tactile models, the sustainability of digital systems, etc., can impact long-term sustainability. The other factor that must be taken into consideration is the accessibility and conservation of original artifacts since the museums should make sure that accessibility does not affect the standards of conservation. Moreover, the continuation of the digital divide underscores the importance of inclusive approaches that may deal with the differences in technology access and literacy. The challenges have highlighted the need to plan and allocate resources strategically during the implementation of accessibility initiatives.

The results of this research indicate that effective implementation of the 3D modeling technologies involves a relatively complex and systematic process that is based on general design shouldals. Museums have to strive to integrate the tactile models with immersive technologies, digital platforms and highly trained staffs into a holistic approach to accessibility that meets the needs of various audiences. This will help not only to increase the inclusiveness but also to improve the overall experience of visitors as it will encourage active and personal interaction with cultural heritage. Also, 3D technologies can be scaled which creates the potential of collaboration, digital preservation, and outreach education; especially in areas where physical museum materials are limited. With these practices, museums have the ability to become the leaders in inclusive cultural activities and innovation.

To conclude, the findings prove that 3D models and related technologies can bring a change in terms of accessibility in museums and make the experiences

multisensory, interactive, and inclusive. The following innovations transform the old paradigm of engagement in the museums to active engagement. Nevertheless, they can only succeed when implemented thoughtfully, evaluated constantly and committed to by the institution. With combination of technological progress and user-focused design and organization, the museums will be able to develop the long-term and significant solutions to accessibility that will guarantee cultural heritage to be accessible to everyone.

Conclusion and Future Scope

Customizable Learning Experiences: Interactive 3D-rendered exhibitions allow visitors to create their own learning experiences, by choosing which particular aspects they want to focus on and being able to access more detailed information, on their own preferences. Such customization increases interaction and learning.

Legal and Ethical Considerations: Accessibility is a legal concept in most jurisdictions and also a moral obligation. As an example, the Americans with Disabilities Act has required museums to offer accessible services to persons with disabilities such as the visually or sensory impaired persons.

Difficulties and Deliberations: Although the use of 3D modeling and interactive technologies have many advantages, the issues that the museums have to think about include the cost of the implementation process, the staff training, and the necessity to strike the balance between the technological advancement and the maintenance of the traditional exhibition experiences.

Through the adoption of 3D modeling and interactive displays, museums will be able to develop more interactive, diverse, and educational experiences and make cultural heritage accessible to everyone.

Notes:

(1) McFaddin-Ward House. Before her death in October 1982 Mamie McFaddin Ward set plans to turn the McFaddin home, located at 1906 McFaddin Avenue in Beaumont, into a museum, a project for which she established the Mamie McFaddin Ward Heritage Foundation. The museum includes the house, carriage house, and collection, which the McFaddin family acquired between the 1890s and 1940s. It exemplifies the manner of living of a wealthy Southeast Texas family between 1907 and 1950. In July 1983 the board hired its first director, and the museum opened in March 1986.

(2) The virtual tour uses CatalogIt to display extensive details about the home, its history, and its objects, including the following information:

Welcome to the McFaddin-Ward house Virtual Tour.

Once inside, Click and drag to look around. Use your mouse or trackpad scroll to zoom in and out. You can move through the house in one of three ways:

* Clicking on any directional link found within our virtual space

* By opening the tour map with the Map icon and clicking a room, or

* Using the tour Navigation menu in the top left corner of the view.

Click the doors to enter our home.

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