Co-designing Immersive and Inclusive Virtual Museum with children and People with Disabilities: a Pilot Study

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***Abstract*— Immersive virtual environments represent a great opportunity for museums to enhance visitor experience through edutainment. However, to provide an enjoyable entertainment and learning experience for all visitors, including people with disabilities, the virtual museum must not only be accessible, but also inclusive: they must provide greater equality and cultural and learning opportunities for all social groups. To achieve this goal, the concept of Universal Design needs to evolve into a user-centered approach where people are involved in co-designing the virtual museum experience. In this context, the article describes a pilot study conducted at the University of Macerata, which explores the possibility of using high-fidelity prototyping in a virtual laboratory to support the co-creation of an immersive virtual museum environment with relevant target users, including children and people with disability, from the earliest design stages. The paper presents the results of the co-design process and discusses its implications in defining design requirements to ensure the accessibility of immersive solutions for cultural heritage.**

Keywords—Virtual Museum, Immersive Virtual Reality, Inclusive education, Inclusive Museum

I. Introduction

In the last three decades, the emergence of what has been called "new museology" [1] and the need to cope with increasing competition in the so-called "experience economy" [2] have led museum institutions to gradually, but radically, transform their relations with society and communities: from institutions focused on the preservation and research of collections, they are gradually and partially evolving into spaces of participation and co-creation of cultural messages [3, 4]. Museums must not only fulfill their educational mission, but also provide engaging and remarkable experiences to attract as many visitors as possible, better meet their needs and expectations, and increase their willingness to revisit and recommend, thereby growing audiences and increasing ticket sales and museum sustainability [5]. In other words, today's museums must enhance the visitor experience through edutainment (education and entertainment), providing an authentic and memorable experience with artifacts.

In this context, new eXtended Reality (XR) technologies represent crucial tools for the promotion of exhibitions, drastically changing the way they are conceived and organized, and reach audiences. Immersive virtual reality (VR) is playing an increasingly important role, as it allows visitors to perceive virtual images of artifacts as authentic and to obtain information about the collections in an entertaining way [4]. In addition, it can improve museum accessibility by allowing visitors to access inaccessible locations or objects [6]. Numerous museums (e.g., British Museum, the Prado Museum, the Vatican Museum) have adopted VR to provide spectacular experiences for their visitors.

Based on the results of a recent study [3], immersive VR with Head Mounted Display (HMD) seems to be the technology of choice to maximize visitor interest and satisfaction (especially young people) and create memorable museum experiences that maximize Pine & Gilmore's 4Es (i.e., education, entertainment, escapism, esthetics) [2]. However, to ensure enjoyable edutainment experiences virtual museums must be inclusive. This requires the design of virtual environments in order to meet as many visitor requirements as possible, including those with disabilities. To this end, several research try to address this issue, starting from the application of accessibility guidelines, e.g., WCAG 2.1 [7], or proposing specific methods and tools to ensure accessibility for people with disabilities (e.g., low vision [8], learning disabilities [9], intellectual disabilities [10], autism [11]). Nevertheless, museum inclusiveness does not depend only on physical accessibility aspects, but also to the peculiarities of its users [12, 13], so that to ensure virtual museum inclusiveness is a rather difficult and complex task that must consider many aspects. The challenge facing is to provide greater equality and cultural and learning opportunities for all social groups, from an inclusion perspective that aims to respond to the complexity of society [14, 15].

To achieve this goal, the concept of Universal Design (UD) [16] needs to evolve into a user-centered approach where people can participate in designing an entertainment and learning environment that simply meets their needs and expectations so that they can use it efficiently [17]. Design methods and processes are crucial for the effective development of VR, to ensure inclusive virtual museum experiences, and deserve further studies [18]. However, research appears to agree that user-centered design (UCD) is

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DOI 10.1109/CSCI58124.2022.00370

the preferred approach for developing immersive solutions for cultural heritage [19], as this approach also underlies design for user empowerment [20]. So that, there is a call for more studies to improve user-centered design practices, to ensure that the virtual experiences are designed and developed upon a full understanding of the needs, expectations and requirements of visitors [18, 21].

In this context, this research aims at exploiting the possibility of using high-fidelity prototyping, within a virtual lab, to enable co-design activities with people with disabilities useful to support design requirement definition, to ensure the accessibility of immersive solutions for cultural heritage. The paper describes a pilot study carried out at the University of Macerata to support the co-creation of an immersive virtual museum environment with relevant target users, including children and people with disabilities.

II. Research Background

A. Accessibility criteria for an inclusive virtual museum

In general, accessibility issues that may arise in physical museums overlap with those in the virtual museum. To be considered inclusive, a museum must meet accessibility requirements: it must ensure that access to its environments and content is barrier-free [7]. Such barriers may be present at the spatial, sensory, or intellectual level (e.g., uneven paths, mono-sensory information, excessive complexity of language used in descriptions). Over the years, several guidelines have been developed, which provide several criteria about how to improve museum access for people with learning disabilities and intellectual disabilities. Based on a recent review, the main guidelines currently available (i.e., [22], [23], [24], [25]) manly provide criteria that can be clustered into three categories [26]: Orientation and Guidance, addresses the design and presentation of the exhibit and the need for a guidance system; Exhibits, concerns exhibits feature and presentation; Content, provides information about how the text can be presented to the target audience to promote better understanding. Most of them can be directly applied also for the construction of virtual museums. However, coping with these criteria does not ensure immersive virtual museum accessibility. In fact, although immersive VR offers new opportunities to include people with disabilities and make museums more accessible, it also presents some problems. For example, interaction in immersive VR, mainly based on head movement and the use of a controller for each hand, requires more physical dexterity than regular controllers or keyboards [27], and can be a huge barrier for people with motor disabilities. Using HMD can be impossible not only for blind people, but also for visually impaired people with unequal vision in one eye or stereo blindness [28], given that it is usually impossible to wear glasses under the HMD. Moreover, moving within the virtual environment can cause cybersickness and disorientation [29]. This requires affording further accessibility criteria.

As far as we know, there are no specific guidelines for improving the accessibility of immersive virtual museums. Notwithstanding, a recent study [30] provides a review of accessibility guidelines available for immersive VR games, which can be applied to ensure the accessibility of any VR application. They mainly refer to two sources: XR Accessibility User Requirements [27], published by APA Working Group of W3C, and the Oculus VRCs "Accessibility Requirements" [31], which provides recommendations to make Oculus VR apps more accessible.

B. Methods to support the design of inclusive museum

Design methods and processes are crucial for the effective development of VR, to ensure inclusive virtual museum experiences, and deserve further studies [18]. However, several researches [18, 19, 32, 33] agree that UCD represents the approach of choice for the development of immersive solutions in line with the principles of UD [34], to mediate and support cultural heritage experiences, so as to empower users [20].

Based on standard ISO 9241-210:2010, a proper UCD process is characterized by the following 4 iterative steps [35]: a) identification of users' needs and establishment of requirements for design; b) development of alternative solutions to meet such needs; c) building of interactive prototypes which can be communicated and assessed; d) evaluation of what is being built throughout the process and of the user experience it offers. Over the years, several methods have been proposed to support UCD practices to better consider the dynamic nature of users abilities [36]. For example, User Sensitive Inclusive Design [37] and Ability-based Design [38] have been introduced in the context of ICT products to support the design team in developing empathy for people with disabilities and promote the development of adaptable interfaces based on user needs. However, there is still a call for more studies to improve user-centered design practices, to ensure that the virtual experiences are designed and developed upon a full understanding of the needs, expectations, and requirements of museum visitors [18, 21]. Co-design approaches seem to be fundamental to integrate multiple perspectives related to lived experiences, which is extremely important when designing with people with different abilities [39]. However, traditional techniques have problems related to the difficulty of communication with people with disabilities, who are often approached through "proxy" people (e.g., parents, teachers, caregivers), with consequent unequal power relations related issues [40].

III. Pilot Study

This study was conducted with the aim of exploring the use of virtual prototyping in the co-design of an immersive and inclusive virtual museum environment with people with specific learning disorders and mild intellectual disability. Co-design activities were carried out according to the method described below.

A. The proposed method

The proposed method is characterized by two phases:

a) Construction of an adaptable and immersive virtual co-design environment. This phase involved a multidisciplinary design team, including experts in: UX design, special pedagogy and Easy-to-Read language, virtual reality application design, art history, learning disabilities and intellectual disabilities. The design activities were carried out iteratively, with the goal of developing an initial concept of an immersive virtual museum environment that complies with the accessibility guidelines shown in Table 1. This environment represents the starting concept that was used to conduct subsequent co-design activities with end users. The virtual environment used for the research was developed in Unity 3D (https://unity.com/). It consists of a floor plan including several rooms, decorated with polychrome marble and Ionic-style columns, through which an exhibition of archeological findings takes place.

The asset used for the findings are digital copies of finds, part of the collections of the National Archaeological Museum of Sannio Caudino in Benevento and the Archaeological Museum of Carife in the province of Avellino, realized using a high-fidelity 3D color scanner (i.e., EinScan Color Pack [41]).

The environment is completed by some monitors and posters used to provide multimodal information of the exhibit. The starting adaptable features include:

- Adjustment of environment light exposure and color temperature (Figure 1);
- Adjustment of the focus level, through the setting of vignetting effects (Figure 2), which allow the width of the field of view to be narrowed;
- Possibility to choose between different museum guide modalities: text descriptions with highly readable fonts (i.e., OpenDyslexic) or audio / video guide that repeats slavishly the text of the description, which can be turned on/off by the user through a dedicated button (Figure 3).
- Possibility to navigate the environment with mouse and keyboard, with a gamepad or by teleporting to the location and then exploring the surrounding space within a range of 2 meters, with natural movements (i.e., walking).

TABLE I. DESIGN CRITERIA TO ENSURE ACCESSIBILITY OF IMMERSIVE VIRTUAL MUSEUM

Exhibits	– Generous room design – Call for action – Enough space between exhibits – 360° view of some exhibits – Economical use of effects – Easy to handle – Use of different media – Movies in simplified language
Content	– Easy-to-read information – High-contrast layout – Big font – Text-to-speech system available – Visualization with pictorial language – Information material should be colorfully illustrated
Access to VR application	– Enable people to edit brightness of their display – Provide customized high contrast skins for the environment to suit luminosity and color contrast requirements – Allow multiple input methods to be used at the same time – Applications should support multiple locomotion style – Ensure fine motion control is not needed to activate an input – Ensure field of view in immersive environments, are appropriate, and can be personalized - so users are not disorientated – Avoid VR simulation sickness triggers

b) Iterative co-design and testing sessions: Co-design activities have been carried out at the virtual laboratory of the Research center of Teaching and learning, Inclusion, Disability, and Educational Technology (TIncTEC) of University of Macerata. They lasted three days, and involved a total of 30 people: 10 children (5 aged 6-10, 5 aged 11-13), 5 teenagers aged 14-19, 15 adults (5 aged 20-25, 5 aged 30-39, 5 aged 40-59). At least 2 people with disabilities were included for each age group, including: specific learning disorders, intellectual disability, Attention-Deficit/Hyperactivity Disorder, high-functional autism (HFA) and physical disability. Participants were divided into six groups of equal size (5 subjects each) and similar people characteristics. Each group took part in co-design activities in consecutive design iteration stages, so that their design contributions have been used to improve the design solution following an incremental process.

Each group, one user at a time, has been asked to interact with the environment. During the interaction, they were encouraged to describe their experience with the virtual museum environment through semi-structured interviews designed to assess the users' opinion about the features, so as to highlight its strengths and limitations.

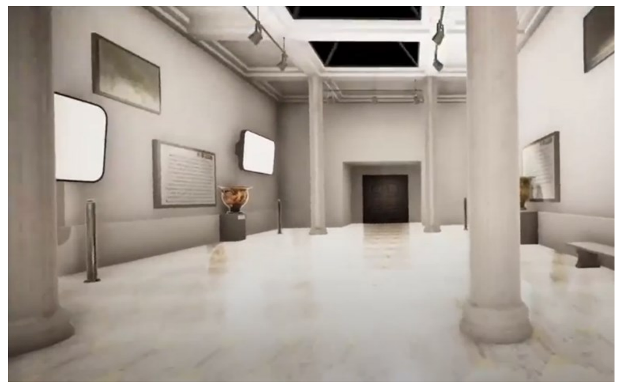

FIG. 1. EXAMPLE OF LIGHT CONFIGURATION OF THE FIRST VERSION OF THE VIRTUAL MUSEUM ENVIRONMENT.

FIG.2. EXAMPLE OF VIGNETTING EFFECT.

FIG. 3. EXAMPLE OF EXHIBITION DISPLAY: THE DIGITAL MODEL OF AN ARCHAEOLOGICAL ARTIFACT, DESCRIPTIVE TEXT, AND THE SCREEN FOR VIEWING THE VIDEO GUIDE.

The tool used to allow navigation within virtual reality consists of a headset Oculus Quest 2 [42] equipped with two multifunction controllers. The headset is connected to a PC workstation running the Unity application in the "game view" modality using a usb cable. This enables environment co-design, through the possibility of implementing some environment design adjustment in very short time (in the order of a few minutes). The subjective view of the environment visualized by the user through the headset is simultaneously shown on a large screen inside the laboratory room that allows the co-design team to monitor the activity of the users during the immersive experience and at the same time acts as a video source to be screen-captured, to record a video of the user interaction with the environment. Based on the results of each co-design session, the virtual museum features are updated as difficulties of use are encountered, in order to achieve the greatest possible accessibility and user experience.

B. Results

Six versions of the software have been developed. Table II shows the main features (on the row) implemented by the various versions of the virtual museum software application (on the columns).

TABLE II. PROTOTYPE VERSIONS. MAIN FEATURES.

	PROTOTYPE VERSIONS						
FEATURES	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**
Adaptable camera exposure	X	X	X	X	X	X	X
Personalized light temperature	X	X	X	X	X	X	X
Focus level adjustment	X	X	X	X	X	X	X
Multimodal museum guide	X	X	X	X	X	X	X
Multimodal environment navigation	X	X	X	X	X	X	X
Video description		X	X	X	X	X	X
Adding of Keyboard control		X	X	X	X	X	X
Reduction of environment dimension (One room per time)		X	X	X	X	X	X
Room decoration improvements			X	X	X	X	X
Start/stop of audio/video descrition by proximity			X				
Start/stop of audio/video descrition by button				X	X	X	X
Possibility to choose the font of textual descriptions				X	X	X	X
Improvement of keyboard controls						X	X
Improvement of exhibition positions					X		X
Play mode option (Oculus/Gamepad)						X	X
Visualization of keyboard legenda						X	X

During the preliminary steps of co-design with people with intellectual disabilities, it was necessary to modify and implement the interaction interfaces created into the virtual environment to increase both usability and interactivity. As a result, the second version included the possibility to control movement within the virtual environment even by mouse and keyboard. Moreover, to reduce cognitive load, the exhibition path was reduced as well, so that the user can explore one room at a time (in the first version the exhibition route takes place along three rooms).

In the third revision, improvements were made to the decoration elements of the environment (e.g., the reflectivity of the floor was reduced, to better simulate a marble covering). In addition, starting and stopping audio descriptions based on the user's proximity to the artifact that is the subject of the audio description was incorporated.

This feature was later dropped in the fourth version, in favor of a start and stop control that requires user input (i.e., pushing a highly visible red button located near the exhibit). The possibility to choose between several fonts in addition to the OpenDyslexic was also added (i.e., the serif font Times New Roman and a sans-serif font Arial).

FIGURE 4. THE THIRD PROTOTYPE VERSION.

The fifth revision of the software introduced improvements related to the placement of artifacts within the virtual environment, and in the sixth revision, keyboard navigability was enriched by displaying an explanatory legend. In addition, the ability to navigate the environment by means of a gamepad was added.

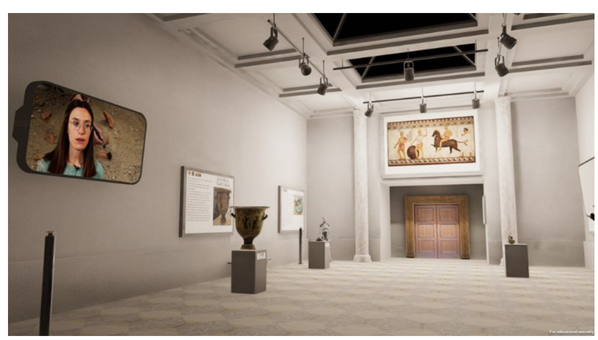

FIGURE 4. THE SEVENTH PROTOTYPE VERSION.

Finally, to further reduce cognitive load, facilitating an overall view of the exhibition, in the seventh and final revision (Figure 6) the architectural appearance of the room was changed: the columns originally arranged to delimit the room in three sections were placed as decoration on the walls.

IV. Conclusion

In recent years a number of studies have been conducted on the use of immersive technologies in museum education, demonstrating how virtual reality can increase multisensory engagement and enhance the visitor experience within museums [43, 44, 45, 46]. Although the potential of immersive technologies has not been fully explored, they could be considered a valuable tool for creating inclusive educational experiences aimed at fostering the teaching-learning process of cultural heritage [47]. In this regard, the following research aims at the realization of a virtual museum developed with the Unity 3D graphics engine that includes high definition digital copies of real archaeological finds. A pilot study was conducted involving children and people with disabilities in the co-design of the virtual environment, in order to ensure an accessible and inclusive virtual museum experience. Future research perspectives will be aimed at investigating other possible configurations in the co-design process that could be effective in creating an inclusive environment during the museum experience. However, the results of this study may have a broader impact, as it provides new insights and guidelines for improving the accessibility of immersive virtual environments, with the goal of enabling people, to the maximum extent possible, to visit cities and natural environments otherwise inaccessible to most people (e.g., underwater depths, mountaintops), so as to enhance the accessibility of video games exploiting immersive VR. Future studies should be conducted to evaluate the usefulness of the proposed co-design process in supporting the development of accessible virtual environments in other application contexts.

Acknowledgment

We thank Vincenzo Zuccaro, director of the National Archaeological Museum of Sannio Caudino in Benevento and Flavio Castaldo, director of the Archaeological Museum of Carife for making digital copies of part of their collections available.

References

[1] Vergo, P. (1989). New Museology, Reaktion books, London.

[2] Pine B.J., & Gilmore, J. H. (1998). Welcome to the experience economy. Harvard business review, 76(4), 97-106.

[3] Leopardi, A., Ceccacci, S., Mengoni, M., Naspetti, S., Gambelli, D., Ozturk, E., & Zanoli, R. (2021). X-reality technologies for museums: a comparative evaluation based on presence and visitors experience through user studies. Journal of Cultural Heritage, 47, 188-198. Doi: https://doi.org/10.1016/j.culher.2020.10.005.

[4] Lee, H., Jung, T. H., tom Dieck, M. C., & Chung, N. (2020). Experiencing immersive virtual reality in museums. Information & Management, 57(5), 103229. Doi: https://doi.org/10.1016/j.im.2019.103229.

[5] Radder, L., & Han, X. (2015). An examination of the museum experience based on Pine and Gilmore's experience economy realms. Journal of Applied Business Research (JABR), 31(2), 455-470. Doi: https://doi.org/10.19030/jabr.v31i2.9129.

[6] Jung, T., & Michopoulou, E. (2019). Experiencing virtual reality in heritage attractions: Perceptions of elderly users. In Augmented Reality and Virtual Reality (pp. 89-98). Springer, Cham. Doi: , https://doi.org/10.1007/978-3-030-06246-0_7.

[7] Rojas, H., Renteria, R., Acosta, E., Arévalo, H., & Pilares, M. (2020, October). Application of accessibility guidelines in a virtual museum. In 2020 3rd International Conference of Inclusive Technology and Education (CONTIE) (pp. 73-79). IEEE. Doi: https://doi.org/10.1109/CONTIE51334.2020.00022.

[8] Zhao, Y., Cutrell, E., Holz, C., Morris, M. R., Ofek, E., & Wilson, A. D. (2019, May). SeeingVR: A set of tools to make virtual reality more accessible to people with low vision. In Proceedings of the 2019 CHI conference on human factors in computing systems (pp. 1-14). Doi: https://doi.org/10.1145/3290605.3300341.

[9] Münch, L., Heuer, T., Schiering, I., & Müller, S. V. (2022). Accessibility Criteria for an Inclusive Museum for People with Learning Disabilities: A Review. In International Conference on Human-Computer Interaction (pp. 371-385). Springer, Cham.

[10] Bushra, A., Mahmood, O., & Yousef, A. (2021). The learning disabled students and incorporating the virtual museum: Analysis study. Doi:

[11] Garzotto, F., Matarazzo, V., Messina, N., Gelsomini, M., & Riva, C. (2018, October). Improving museum accessibility through storytelling in wearable immersive virtual reality. In 2018 3rd Digital Heritage International Congress (DigitalHERITAGE) held jointly with 2018 24th International Conference on Virtual Systems & Multimedia (VSMM 2018) (pp. 1-8). IEEE. Doi: https://doi.org/10.1109/DigitalHeritage. 2018.8810097.

[12] Giaconi, C., Rodrigues, B. (2014) Organization of Time and Space for the Inclusion of Subjects with Autism. Educação & Realidade 39 (3): 687–705. Doi: https://doi.org/10.1590/S2175-62362014000300004.

[13] Giaconi, C., Ascenzi, A., Del Bianco, N., D'Angelo, I., & Capellini, S. A. (2021). Virtual and Augmented Reality for the Cultural Accessibility of People with Autism Spectrum Disorders: A Pilot Study. International Journal of the Inclusive Museum, 14(1). Doi: https://doi.org/10.18848/1835-2014/CGP/v14i01/95-106.

[14] Carrara, E. (2014) Verso un museo inclusivo: presupposti e prospettive in risposta al cambiamento sociale" [Toward an Inclusive Museum: Assumptions and Perspectives in Response to Social Change]. IL Capitale Culturale: Studies on the Value of Cultural Heritage 9:169–188. Doi: https://doi.org/10.13138/2039-2362/811.

[15] Muscarà, M., Sani, C. (2019) Accessibility to Cultural Heritage, some project outcomes. Education Sciences & Society-Open Access, 10(1): 244-280. Doi:

[16] Persson, H., Åhman, H., Yngling, A. A., & Gulliksen, J. (2014). Universal design, inclusive design, accessible design, design for all: different concepts—one goal? On the concept of accessibility—historical, methodological and philosophical aspects. Universal Access in the Information Society, 14(4), 505–526. Doi: https://link.springer.com/ article/10.1007/S10209-014-0358-Z.

[17] Giaconi, C., Del Bianco, N., D'Angelo, I., Halwany, S., & Capellini, S. A. (2021). Cultural accessibility of people with Intellectual disabilities: A pilot study in Italy. International Journal of Special Education and Information Technologies, 7(1), 16-26. Doi: https://doi.org/10.18844/jeset.v7i1.7013.

[18] Marasco, A., & Balbi, B. (2019). Designing accessible experiences for heritage visitors through virtual reality. E-review of Tourism Research, 17(3).

[19] Balbi, B., & Marasco, A. (2021). Co-designing Cultural Heritage Experiences for All with Virtual Reality: a Scenario-Based Design approach. Umanistica Digitale, (11), 71-98. Doi: http://doi.org/10.6092/issn.2532-8816/1368671.

[20] Ladner, Richard E. 2015. "Design for user empowerment". Interactions 22(2): 24-29. https://doi.org/10.1145/2723869.

[21] Han, D. I. D. & tom Dieck, M. C. (2019). Calling for user-centric VR design research in hospitality and tourism. Hospitality & Society, 9(2), 237-246. Doi: https://doi.org/10.1386/hosp.9.2.237_7.

[22] Deutsches Seminar für Tourismus Berlin e.V. (DSFT): Reisen für Alle – Qualitätskriterien: Anforderungen für Menschen mit kognitiven Beeinträchtigungen [Travel for everyone – Quality criteria: Requirements for people with cognitive impairments] (2020). https://www.reisen-fuer-alle.de/qualitaetskriterien_fuer_menschen_mit_kognitiven_beeintraechtigungen_329.htm

[23] Interreg CENTRAL EUROPE. COME-IN! GUIDELINES (2019). http://www.central2020.eu/Content.Node/COME-IN/COME-IN-Guidelines-FINAL-English-version.pdf

[24] Landesverband der Museen zu Berlin e.V. (LMB) & Senatskanzlei Berlin – Kulturelle Angelegenheiten. DESIGN FOR ALL - Barrierefreie Ausstellungen in Berlin – Checkliste Verstehen [DESIGN FOR ALL – Barrier-free exhibitions in Berlin – Understand checklist] (2011). https://neu.lmb.museum/wp-content/uploads/2021/04/04-checkliste-verstehen.pdf

[25] Deutscher Museumsbund (DMB): Das inklusive Museum – Ein Leitfaden zu Barrierefreiheit und Inklusion [The inclusive museum – A guideline to accessibility and inclusion] (2013).

https://www.museumsbund.de/wp-content/uploads/2017/03/dmb-barrierefreiheit-digital-160728.pdf

[26] Münch, L., Heuer, T., Schiering, I., & Müller, S. V. (2022). Accessibility Criteria for an Inclusive Museum for People with Learning Disabilities: A Review. In International Conference on Human-Computer Interaction (pp. 371-385). Doi: https://doi.org/10.1007/978-3-031-05039-8_27.

[27] W3C (2020). XR Accessibility User Requirements. Available at: https://www.w3.org/TR/xaur/ (Accessed October 17, 2022).

[28] Hamilton, I. (2018). A Practitioner Reflection on Accessibility in Virtual Reality Environments. Comput. Game J. 7, 63–74. Doi: https://doi.org/10.1007/s40869-018-0061-z.

[29] Wang, X., Liang, X., Yao, J., Wang, T., & Feng, J. (2021). A study of the use of virtual reality headsets in Chinese adolescents with intellectual disability. International Journal of Developmental Disabilities, 1-9. Doi: https://doi.org/10.1080/20473869.2021.1970938.

[30] Heilemann, F., Zimmermann, G., & Münster, P. (2021). Accessibility guidelines for VR games-A comparison and synthesis of a comprehensive set. Frontiers in Virtual Reality, 119. Doi: https://doi.org/10.3389/frvir.2021.697504.

[31] Oculus (2020). Quest Virtual Reality Check (VRC) Guidelines. Available at: https://developer.oculus.com/distribute/publish-quest-req/ (Accessed October 17, 2022).

[32] Beltrán, M. E., Ursa, Y., de los Rios, S., Cabrera-Umpiérrez, M.F., Arredondo, M.T., Páramo, M., Prados, B., Pérez, L.M. (2014) Engaging people with cultural heritage: Users' perspective". In Universal Access in Human-Computer Interaction. Universal Access to Information and Knowledgeedited by Constantine Stephanidis, Margherita Antona, 639-649, Springer, Cham. Doi: https://doi.org/10.1007/978-3-319-07440-5_58

[33] Bettelli, A., Orso, V., Pluchino, P., Gamberini, L. (2019) An enriched visit to the botanical garden: co-designing tools and contents. In Proceedings of the 13thBiannual Conference of the Italian SIGCHI Chapter: Designing the next interaction, 1-5. Doi: https://doi.org/10.1145/3351995.3352034.

[34] Story, M. F., J. L. Mueller, and R. L. Mace, The Universal Design File: Designing for People of All Ages and Abilities, Raleigh, N.C.: Center for Universal Design, North Carolina State University, 1998.

[35] Ceccacci, S., Generosi, A., Giraldi, L., & Mengoni, M. (2017, September). An user-centered approach to design smart systems for people with dementia. In 2017 IEEE 7th International Conference on Consumer Electronics-Berlin (ICCE-Berlin), pp. 273-278.

[36] Ceccacci, S., Giraldi, L., & Mengoni, M. (2017, July). A Systematic Approach to Support Conceptual Design of Inclusive Products. In International Conference on Universal Access in Human-Computer Interaction (pp. 43-55). Springer, Cham.

[37] Wobbrock, J. et al., 2011. Ability-based design: Concept, principles and examples. ACM Transactions on Accessible Computing (TACCESS), Vol. 3, No. 3, pp. 1-36.

[38] Newell, A. F. & Gregor, P., 2000. User Sensitive Inclusive Design – in search of a new paradigm. A.C.M. Conference on Universal Usability, Washington, DC Nov. 2000, pp. 39-44.

[39] Harris, M. C., Brown, D. J., Vyas, P., & Lewis, J. (2022). A methodology for the co-design of shared VR environments with people with intellectual disabilities: Insights from the preparation phase. In International Conference on Human-Computer Interaction (pp. 217-230). Springer, Cham.

[40] Raman, S., & French, T. (2021). Enabling genuine participation in co-design with young people with learning disabilities. CoDesign, 1-17.

[41] Einscan Color scanner. https://www.einscan.com/handheld-3d-scanner/color-pack (Accessed October 17, 2022)

[42] Oculus Quest 2. https://www.meta.com/it/quest/products/quest-2/ (Accessed October 17, 2022)

[43] De Simone, G., Di Tore, S., Maffei, S., Sibilio, M., & Todino, M. D. (2017). L'utilizzo di tecnologie head-mounted display a supporto della didattica attraverso ambienti di apprendimento virtuali in contesti non formali. Italian Journal Of Educational Research, 165-176.

[44] Coppola, S., & Zanazzi, S. (2020). L'esperienza dell'arte. Il ruolo delle tecnologie immersive nella didattica museale. FORMAZIONE & INSEGNAMENTO. Rivista internazionale di Scienze dell'educazione e della formazione, 18(2), 036-049. Doi: https://doi.org/10.7346/-fei-XVIII-02-20_04

[45] Rossi, D., Meschini, A., Feriozzi, R., & Olivieri, A. (2018). Cose dell'altro mondo. La realtà virtuale immersiva per il patrimonio culturale. Ambienti digitali per l'educazione all'arte e al patrimonio, 240-256.

[46] Carci, G., Caforio, A., & Gamper, C. (2019). Digital technologies and museums: augmented reality, learning and audience development. Form@ re-Open Journal per la formazione in rete, 19(1), 274-286 .DOI: https://doi.org/10.13128/formare-24619

[47] Todino, M. D., Campitiello, L., & Di Tore, S. (2022). The Use of Archaeological Finds to Realize Digital Assets Through 3D Scanning: From Presence to Distance in Museum Education. International Journal of Digital Literacy and Digital Competence (IJDLDC), 13(2), 1-13.