Co-design of immersive virtual learning environments: a pilot study involving people with intellectual disability and SLDs

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Abstract

This paper describes a pilot study conducted at the University of Macerata, within the project Inclusion 3.0. It aims to explore the possibility of using high-fidelity prototyping in a virtual laboratory to support the co-creation of an immersive virtual learning environment with people with disability and Specific Learning Disorders (SLDs), 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

Inclusion; project; SLD; specific learning disorders; disability; virtual;

1. Introduction

Inclusion 3.0 is a project initiated by the University of Macerata in July 2017, designed to implement design actions in the direction of university inclusion of students with disabilities and Specific Learning Disorders. The significance of the Inclusion 3.0 project fits into a macro level of connection with international scenarios, and in especially with the European Horizon 2020 program [1], and in a micro level of responding to the national trend of growth in the enrollment of students with disabilities and SLDs in the university environment, which brings with it the need to build university teaching paths oriented to personalization inclusion and innovation.

Despite research recognizing the value of the study method as the primary compensatory tool [2, 3] Secondary school students and university students with disabilities and ASDs show deficiencies in study method and poor use or low autonomy in the use of compensatory tools [3, 4]. In detail, Censis records an adequate level of satisfaction with orientation and disability services of Italian universities, while the degree of satisfaction with the accessibility of educational materials and the use of technological aids [5]. Considering the data, it appears necessary to focus on the experimentation of innovative forms of support for inclusive university didactics, concerning the design of accessible contexts and integrated technological systems capable of promoting accessibility, usability, and sustainability.

In this perspective, we emphasize the targeted and pedagogically oriented use of technologies and methodological paths through a unique aggregate of technological resources that can support students with disabilities and with SLDs. Therefore, the advancement lies in creating an integrated system of technologies. This system, on the one hand, would be capable of responding to the need of students with disabilities and SLDs in finding and interacting with materials and accessible content, on the other hand, to guide teachers in the design of inclusive teaching materials and paths.

This goal can be achieved through a research-action process characterized by three phases:

- Phase One: reconnaissance of technologies and creation of an integrated system of devices;
- Second Phase: Experimentation of technological tools;
- Third Phase: Creation of a permanent co-design laboratory.

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According to this methodological framework, co-design approaches are fundamental to integrate multiple perspectives related to lived experiences, which is extremely important when designing with people with different abilities [6, 7]. However, traditional co-planning techniques present problems related to the difficulty of communicating with people with disabilities, who often respond through the voice of "delegates" (e.g. parents, teachers, caregivers), resulting in unequal power relations. However, traditional co-planning techniques present problems related to the difficulty of communicating with people with disabilities, who often respond through the voice of "delegates" (e.g. parents, teachers, caregivers), resulting in unequal power relations [8]. To overcome these problems and encourage the direct involvement of people with disabilities in the design process, we conducted a pilot study to explore the use of immersive virtual reality by people with specific learning disorders and mild intellectual disabilities. At the same time, they were the co-designer of the informal learning environment, such as a museum, to ensure the design of an inclusive learning experience.

2. The proposed method

Following a user-centred design approach, co-design activities were carried out according to a design process characterized by three main stages:

1. Reconnaissance of available accessibility design guidelines;
2. Construction of an adaptable and immersive virtual co-design environment;
3. Iterative co-design and testing sessions.

The first phase aims to identify design guidelines that may be useful in guiding the definition of an initial design concept. As far as we know, there are no specific guidelines to ensure the accessibility of immersive virtual museums. However, as accessibility issues that may arise in physical museums overlap with those in the virtual museum, we started by considering that the main museum accessibility guidelines currently available (i.e., [9-12]). They provide criteria that can be directly applied also for the construction of virtual museums, which can be clustered into two categories [13]: Exhibits, concerns exhibits feature and presentation; Content, provides information about how the text can be presented to the target audience to promote better understanding. Moreover, to ensure accessibility of VR application, we considered also accessibility guidelines provided by XR Accessibility User Requirements [14], and the Oculus VRCs "Accessibility Requirements" [15]. The considered accessibility guidelines are reported in Table 1.

Table 1
Design criteria to ensure accessibility of immersive virtual museum

Exhibits	Content	Access to VR application
• 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	• Easy-to-read information • High-contrast layout • Big font • Text-to-speech system available • Visualization with pictorial language • Information material should be colorfully illustrated	• 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

The second phase involved a multidisciplinary team, including experts in: UX design, Special Education and Easy-to-Read guidelines, virtual reality application design, art history, learning disabilities and intellectual disabilities. The design activities were carried out iteratively to develop an initial concept of an immersive virtual museum environment accorded to the accessibility guidelines previously identified. This environment represents the starting concept used to conduct subsequent co-design activities with end users. The virtual environment used for the research was developed in Unity 3D (https://unity.comIt consists of a floor plan including several rooms (decorated with polychrome marble and Ionic-style columns) where digital copies of archaeological finds are located. In this virtual environment, monitors and posters are also used to provide information about the exhibit through multiple information channels (Figure 1).

Adaptable features include:

- Adjustment of ambient light exposure and colour temperature;
- Adjustment of the focus level, through the setting of vignetting effects, which allows 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;
- 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).

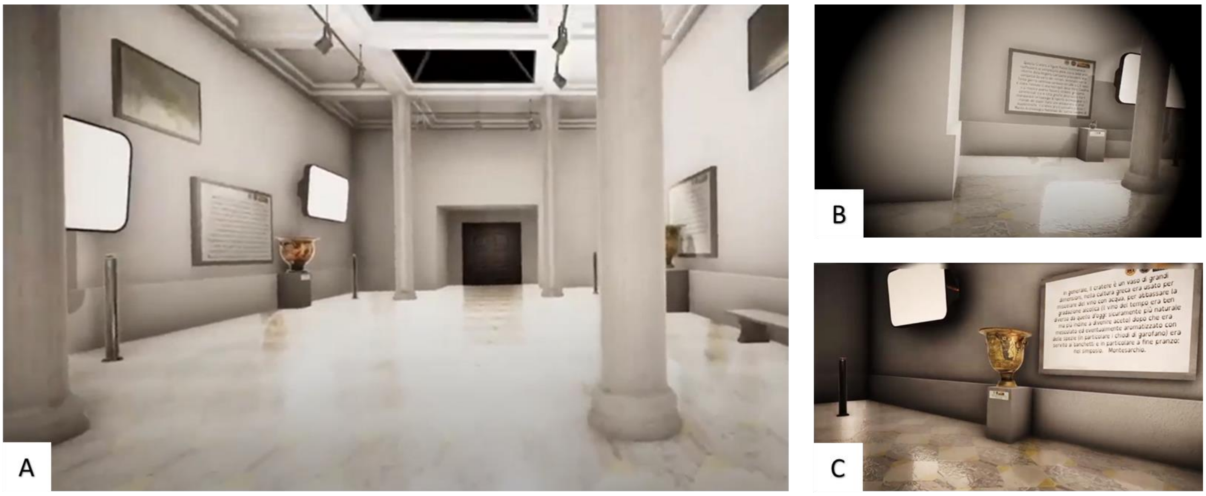

Figure 1: The first design concept: one of the exhibition rooms (A), an example of vignetting effect (B), and an example of an exhibition display (C).

The last phase focuses on co-design activities. Such activities have been carried out at the virtual laboratory of the Research Centre of Teaching and Learning, Inclusion, Disability, and Educational Technology (TIncTEC) of the University of Macerata. This phase lasted three days and involved a total of 30 people: ten children (5 aged 6-10, 5 aged 11-13), five teenagers (aged 14-19), fifteen adults (5 aged 20-25, 5 aged 30-39, 5 aged 40-59). Participants were divided into six groups of equal size (5 subjects each) and similar people characteristics (i.e., age and gender). At least two people with specific learning disorders or intellectual disabilities were included in each group. Each group took part in co-design activities in consecutive design iteration stages so that their design contributions could be used to improve the design solution following an incremental process.

Each group, one user at a time, was 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' opinions about the features to highlight their strengths and limitations.

The tool used to allow navigation within virtual reality consists of a headset, Oculus Quest 2 [16], 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 connection enables environment co-design through the possibility of implementing some environment design adjustments in a short time (a few minutes). The scene of the environment visualized by the user through the headset is simultaneously shown on a large screen inside the laboratory room, allowing the co-design team to monitor the users' activity during the immersive experience. At the same time, this set acts as a video source to record the whole 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 to achieve the greater possible accessibility and user experience.

3. Results

The co-design session resulted in a total of six versions of the software have been developed (Table 2).

Table 2
Features characterizing each prototype version

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

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 also reduced so that the user could explore one room at a time (in the first version, the exhibition route takes place along three rooms). In fact, 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.

In the third revision, the reflectivity of the floor was reduced to simulate a better marble covering. Moreover, starting and stopping audio descriptions based on the user's proximity to the artefact that is the subject of the audio description were incorporated. However, this feature was eliminated in the fourth version in favour of a start and stop control that requires user input (i.e., pushing a highly visible red button near the exhibit). Instead, 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).

The fifth revision of the software introduced improvements related to the placement of artefacts within the virtual environment. The sixth revision enriched keyboard navigability by displaying an explanatory legend. In addition, the ability to navigate the environment using a gamepad was added. Finally, to further reduce cognitive load and facilitate an overall view of the exhibition, in the seventh and final revision (Figure 2), 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.

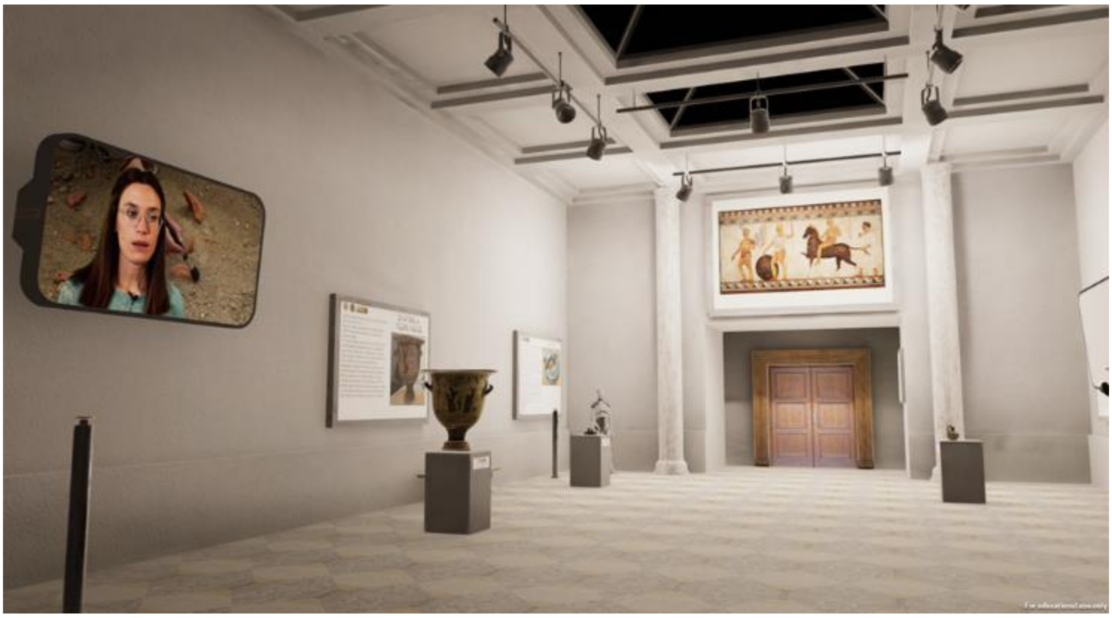

Figure 2: The resulting virtual museum environment

4. Conclusion

Although the potential of immersive technologies has yet to be fully explored, they could be considered valuable tools for creating inclusive educational experiences that foster the teaching-learning process of cultural heritage [17,19-21]. In this regard, the following research aims to realize 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 as co-designer to ensure an accessible and inclusive virtual 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. For example, future applications can be extended to enable people, to the maximum extent possible, to visit cities and natural environments otherwise inaccessible to most people (e.g., underwater depths, mountaintops) and 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.

References

[1] European Horizon 2020 program 1. https://EC.EUROPA.EU/Programmes/horizon2020/en/ (Retrieve on 02/12/2022)

[2] Friso, G., Cornoldi, C., Russo, M. R., Paiano, A., & Amadio, V. (2011). Studio efficace per ragazzi con DSA: Un metodo in dieci incontri. Edizioni Erickson.

[3] Giaconi, C., Capellini, S. A., Del Bianco, N., Taddei, A., & D'Angelo, I. (2018). Study Empowerment for inclusion. Education Sciences & Society-Open Access, 9(2).

[4] Giaconi, C., & Capellini, S. A. (2015). Conoscere per includere. Riflessioni e linee operative. Milano: FrancoAngeli.

[5] Censis (giugno 2017), Accompagnare le Università verso una più ampia integrazione degli studenti con disabilità e DSA, Survey presented at the Convention: "Presente e futuro dei servizi per l'inclusione: Atenei a confronto". Catania: Università degli Studi di Catania. CNUDD (2014), Linee Guida, Bergamo, www.cnudd.it (retrieved on 02/12/2022).

[6] 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.

[7] 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). IEEE.

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

[9] 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

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

[11] 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

[12] 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

[13] 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.

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

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

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

[17] 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.

[18] Ceccacci, S., Generosi, A., Leopardi, A., Mengoni, M., & Mandorli, A. F. (2021). The Role of Haptic Feedback and Gamification in Virtual Museum Systems. Journal on Computing and Cultural Heritage (JOCCH), 14(3), 1-14.

[19] Leopardi, A., Ceccacci, S., & Mengoni, M. (2021, August). A New Paradigm for the Enjoyment and Exploitation of Cultural Heritage Based on Spatial Augmented Reality: The Case of the Ducal Palace of Urbino. In International Design Engineering Technical Conferences and Computers and Information in Engineering Conference (Vol. 85376, p. V002T02A077). American Society of Mechanical Engineers.

[20] Frolli, A., Savarese, G., Di Carmine, F., Bosco, A., Saviano, E., Rega, A., Carotenuto, M., & Ricci, M. C. (2022). Children on the Autism Spectrum and the Use of Virtual Reality for Supporting Social Skills. Children (Basel, Switzerland), 9(2), 181.

[21] Frolli, A., Bosco, A., Lombardi, A., Di Carmine, F., Marzo, S., Rega, A., & Ricci, M. C. (2021). Asperger's and virtual reality. Proceedings http://ceur-ws. org ISSN, 1613, 0073.