Social Virtual Environments: Opportunities and Workflows in Cultural Heritage and Education in Architecture

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Keywords: Virtual Reality, Mozilla Hubs, Virtual Exhibitions, Virtual Tours, VR Headset, Web-Based Applications.

Abstract: The paper analyses the use of social virtual environments in cultural heritage and education in Architecture. Specifically, it aims to trace state-of-the-art and possible developments of a web-based solution based on 3D models and diverse content to create virtual environments that remain rare in the disciplinary field of architectural digital representation and cultural heritage sector but widely used in education. The applicative scenarios presented, using Hubs by Mozilla and Spoke, were developed at the Department of Architecture and Design DAD of Politecnico di Torino. They comprise a series of experiences in communicating didactic activities on the *TeleArchitettura* TA platform and some collaborations with various museums in Italy.

1 INTRODUCTION

Extended Reality (XR) is a term that comprises diverse technologies: virtual reality (VR), augmented reality (AR), and mixed reality (MR). The conceptual definition of XR has been outlined in the *reality-virtuality continuum* that classifies the various possible combinations of digital and physical elements. (Milgram et al., 1995)

Virtual reality is an interactive, participatory environment that could sustain many remote users sharing a virtual place (Gigante, 1993).
VR includes computer applications and programs that create, visualize, and interact with virtual spaces and environments. This technology may consist of graphics engines, VR-developed environments, and specific digital solutions for education, entertainment, training, and others.

Augmented Reality (AR) is a system that enhances the real world by superimposing computer-generated information on top of it. It can include diverse types of information, annotations, audio, images, videos, and 3D models, giving users the perception of interaction with the real world (Wellner et al., 1993).

Finally, Mixed Reality (MR) is a hybrid environment where real-world and digital objects coexist. The user can be immersed in the physical environment using, for example, semitransparent displays or VR headsets and interact with digital elements visible through them (Costanza et al., 2009).

In recent years, significant advances in hardware and software technology have made extended reality technologies more widespread and accessible. COVID-19 has further accelerated the diffusion of technologies such as virtual and augmented reality in education and for the promotion and enhancement of cultural heritage (Alnagrat et al., 2022; Nemo, 2021).

Following the COVID-19 pandemic, new methods and tools have been developed, changing how individuals unable to see each other in person can communicate. In parallel, educational processes have also seen platforms such as Teams and Zoom used at all levels of education for online or blended lectures (Hagler, 2022). However, some platforms with prosocial intents allowed the creation of new spaces, digitally capable of replicating in-person experiences to interact with others. This type of technology differs from the generic virtual reality, where the user is alone within the space. A prosocial virtual environment enables people to embody a virtual avatar and interact with other users in an immersive, three-dimensional virtual space (Martínez-Canos, et al., 2023; Large et al. 2022a; Kolesnichenko, 2019). This path is already well established in gamification and the edutainment

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context, which have created new social presence strategies.

In this direction, Social Virtual Environments SVE have boomed in use during the pandemic period, and the European Union also contributed to financing specific learning units for first and second-grade schools. The intention was to test and set up best practices for these social and virtual learning environments. (Abbate, 2022) *Building with Bits* was a Europeana Initiative mentoring program and educational challenge contributing to the *New European Bauhaus movement* by inviting students and educators to design beautiful and sustainable spaces with Mozilla Hubs (Europeana Pro, 2021).

In universities, on the other hand, new systems for design studio teaching and the development of virtual environments, metaverses, and virtual exhibitions have been created, for example, to answer the need to create habitats for shared exchange, reviews, and for the final presentation of the designed projects themselves. (Smithson, 2021) An early prototype of this type of experience was conceptualized in Italy under the name *Hyspace* (Valenti, 2007).

Regarding the Galleries and Contemporary Art sector, virtual exhibitions have also increased thanks to the non-fungible tokens (NFTs) and the Crypto Art within the Metaverse. (Terry and Keeney, 2022) An iconic initiative was the 2020 edition of *Ars Electronica* which was entirely developed online using Mozilla Hubs and creating 60 rooms with a multitude of contents (Ars Electronica, 2020).

Again, in 2022, Mozilla Hubs was contacted by conceptual artist Ashley Zelinskie on a project with the NASA James Webb team. The output was the New York exhibition *Unfold the Universe: First Light*. The exhibition features her VR artwork *Unfolding the Universe: A NASA Webb VR Experience.*

Indeed, the pandemic has accelerated the digitization of cultural heritage, with museum institutions needing to reach the public through social media, virtual tours, and new media, including gamification and virtual exhibitions. However, it remains a partially unknown tool in cultural heritage; the role of low-cost and less time-consuming VR solutions should be analyzed and understood to highlight its criticality and potential compared to other widely used extended reality tools, such as Unity or Unreal engines, which Heritage Institutions generally prefer.

This became quite clear in drawing and representation, which comprises the knowledge of digital tools to represent design projects. However, it also has documentation and representation of cultural heritage for its purposes.

Therefore, this research focuses on standardizing processes in creating web-based digital content that differs from the existing workflow for creating environments and models for game engines. Specifically, the paper analyzes the web application Mozilla Hubs and some *Hubs rooms* developed to describe diverse and heterogeneous applicative scenarios. The Hubs infrastructure consists of a 3D scene hosted by Mozilla servers called *Hubs room*. Each room has a specific URL address that people can use to reach the SVR space simultaneously and where they can speak, chat, and interact in various ways with others and within the digital environment.

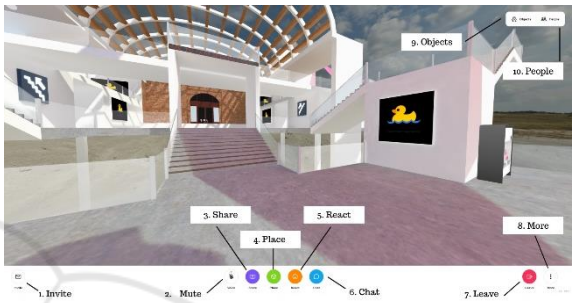


Figure 1: Hubs User Interface.

2 HUBS BY MOZILLA

The project was born in 2014, starting with the AltspaceVR solution, which was, at that time, first tested with one of the prototype visors on the market, an Oculus HD. AltspaceVR was envisioned as a system capable of loading a mobile web browser into a 3D VR environment. It was developed within Unity in a project called Unity Client. Following its failure in 2017, it was evident not only that a new way of communicating and socializing online had been created but also that the biggest beneficiaries of this type of technology were those who could not leave their homes due to illness or social anxiety. Hubs by Mozilla was then released by *The Hubs Team* in 2018 as a system based on WebVR technology, which allowed graphics to be rendered on VR viewers using the browser. Alongside creating an immersive digital environment, there is also the possibility of meeting with other users using personal avatars. In 2019, the COVID-19 pandemic accelerated the expected digital transition for virtual social environments, which was previously unthinkable (Fodor, 2020).

Unfortunately, just as with AltspaceVR, which Microsoft purchased in 2017 and shut down in 2023 (McVeigh-Schultz, 2019), the Mozilla Hubs

adventure has also come to an end. The servers will be shut down on May 31, 2024.

In late 2022, Fodor also released a possible alternative to Hubs: Webspaces. The novel solution is a new way to create self-hosted 3D worlds on the web using HTML. Webspaces don't just run on the web but are built into the web and can be hosted in a GitHub repository. (Fodor, 2022) In particular, the new solution differs from Hubs in its ability to use vox files, a voxel-based file description used to represent assets for 3D games and virtual environments such as Minecraft and MagicaVoxel.

Despite the ominous news and the need to understand how to migrate content developed from Hubs to Webspaces, the paper analyzes some application experiences in the literature that have addressed the development of a social virtual environment using Hubs by Mozilla as a tool.

3 HUBS IN LITERATURE

The analysis started by searching for articles, even those that were not indexed, using the Google Scholar platform. The keywords used were Mozilla Hubs, social virtual reality, and prosocial.

Forty articles, covering the period between 2019 and 2023, were identified and divided according to the year of publication. This identified an incremental increase in scientific production on the topic, consistent with the application's release and progressive deployment in recent years.

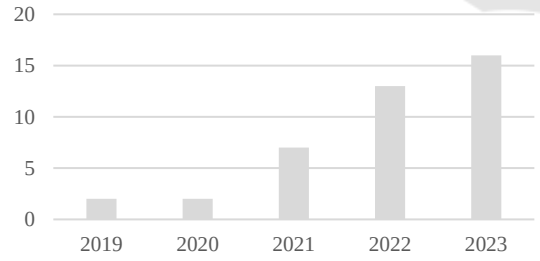


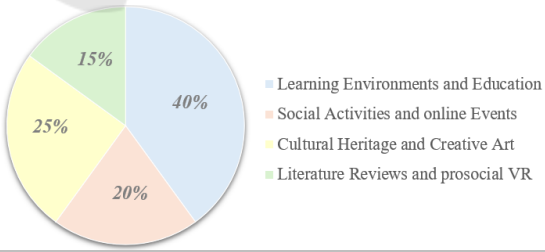
Figure 2: Analysis of references according to years of publication.

These resources are joined by other contributions collected through online searches that are mainly found in the form of blogs or web news. Another interesting research tool turned out to be the Adobe Bēhance portal. Bēhance is the leading online platform for presenting and discovering creative works. Indeed, by using the words Mozilla Hubs within the platform's search engine, it was possible to see how many artists have used the platform to showcase virtual environments created online, documenting them through presentations, portfolios, and videos. This is in line with one of the new professional figures that emerged in conjunction with the advent of Web 3.0 and metaverse: the 'content creator,' which does not involve only individuals, e.g., YouTubers, influencers, or tiktokers, but also companies and cultural organizations, including museums.

Analyzing the forty papers, it is possible to categorize them according to three main applicative scenarios: learning environments and education (blue), social activities and online events (red), and cultural heritage and creative art solutions (yellow). Other papers that have already been cited address literature reviews or methodological approaches to analyzing prosocial activities within virtual spaces (green).

Table 1: List of analyzed references.

Cheng et al. (2022)	*Duester et al. (2023)*
Kolensnichenko et al. (2019)	*Dziwis et al. (2023)*
Martínez-Cano et al. (2023)	*Flyntz et al. (2023)*
McVeigh-Schultz et al. (2019)	*Giovannini (2023a)*
Osborne et al. (2023)	*Giovannini (2023b)*
Wiliamson et al. (2021)	*Giovannini & Bono (2023)*
Gomes et al. (2021)	*Giovannini et al. (2023a)*
Gonsalves et al. (2021)	*Hagler et al. (2022)*
Kumari et al. (2023)	*Lin, J. (2023)*
Large et al. (2022)	*Tsiamalou et al. (2023)*
Le et al. (2020)	*Cowie et al. (2022)*
Lee et al. (2021)	*Eriksson (2022)*
Li et al. (2021)	*Hallewell et al. (2022)*
Shatilov et al. (2023)	*Herman et al. (2022)*
Abbate, 2022	*Lam et al. (2022)*
Anumolu et al. (2021)	*Nirbaya et al. (2023)*
Asino et al. (2022)	*O'Hagan et al. (2023)*
Bedolla et al. (2021)	*Poolsawas et al. (2023)*
Bredikhina et al. (2020)	*Qian (2022)*
Canniff et al. (2022)	*Revianti et al. (2022)*



4 HUBS EXPERIENCES

The series of experiences presented here were conducted at the prototype level both in the field of Cultural Heritage enhancement and in the field of project education in Architecture.

The workflows used in both fields to develop six digital environments highlight the main differences between a virtual exhibition for cultural heritage and a virtual display for project education. They also address the different approaches to creating digital assets, including text, audio, video, images, and 3D models.

The choice of Mozilla Hubs for the experiences developed was mainly based on two main factors: ease of use and the possibility of having a web-based system to access and enjoy the digital environments created. Another factor that influenced the choice was the possibility of having an additional tool, also developed by Mozilla, that would serve to create 3D scenes: Spoke by Mozilla. This type of web-based application does not require the installation of specific software. Still, it is based on retrieving resources already available on the web, interfacing, for example, with online 3D platforms used today as digital galleries or 3D repositories. The proposed projects mainly used SketchFab as the primary 3D models repository and GitHub to store images and audio tracks. Different YouTube accounts were also used to store and retrieve videos.

Figure 3: Spoke elements for creating the 3D scene.

From the virtual environment design perspective, digital assets can be considered as part of a digital ecosystem with a hierarchy between a 'container' and its 'content.'

'*Container*' means the virtual environment with its three-dimensional features that may or may not reflect the physical features of a real environment or digital environments that do not respond to real physical laws. '*Content*,' on the other hand, is the set of resources that populate the created digital environment.

Part of this category are, for example, the objects in a museum collection or the exhibition layout itself (3D), but also the texts and infographics (1D), videos, and images (2D) that create the storytelling paths and narratives within the 3D scene. Audio that narrates and accompanies visitors during the immersive environment visit can also coexist within the system.

The aim is to generate imagery and storytelling models where the immersive and shared experience plays a key role. In addition, the platform also allows the inclusion of animations and physical simulations within the environment, increasing the sense of interaction between the user and the digital environment. This web-based solution introduces a novel way of fruition that is no longer passive but active, interactive, and participatory. Many users can join the Hubs room (container and content) and interact not only with the contents but also with other people and their avatars.

4.1 Cultural Heritage Sector

The first three experiences concern repurposing museum environments and collections from the National Museum in Ravenna, the Egyptian Museum in Turin, and the Museum of Passion in Sordevolo. These Social Virtual Environments (SVE) enhance and communicate cultural heritage, tangible and intangible, through different types of content: texts, images, 360° spherical panoramas, videos, and 3D models. Creating the scenes involved digitizing museum collections (content) and using three-dimensional solid modeling processes for the environment (container).

The 'content,' resulting from reverse engineering processes, was also retopologized to reduce its MB size. Sometimes, the 'container' was also simplified to create a low-poly scene that still evokes real environments using textures developed by photogrammetric acquisition processes.

Both 3D elements for 'container' and 'content' were stored in a SketchFab account to be retrievable by their URL addresses. To satisfy the platform requirements, each 3D model, including 3D mesh, textures, and any other file included with the model, should be under 200 MB in size.

4.1.1 'Porta Aurea Hall' at the Archeological Museum of Ravenna

Inside the hall at the National Museum of Ravenna, entitled 'Porta Aurea Hall,' which consists of two main rooms, there are numerous fragments, some of them belonging to the Porta Aurea, an ancient Roman gate commissioned by Emperor Claudius in 42. B.C. Today, no trace of the ancient monument remains

except where it must have stood, near the Ravenna walls where the ruins of two circular towers that framed it are still located. The project for the virtual environment of the Porta Aurea Hall has the primary objective of providing more information concerning the monument and its original appearance according to past documentary heritage, including drawings and sketches of illustrious authors, including Andrea Palladio, Pirro Ligorio, and Sangallo the Young.

The digital replica of the environment (container) is intended to simulate the room as it appears in reality, but it is completely dedicated to the monument's narrative. In the scene, all fragments that do not belong to Porta Aurea have been removed, and the spaces have been used to display historical and archival documents, a timeline of historical representations, survey drawings, and a hypothesis of virtual reconstruction displayed with referenced fragments, addressing the theme of documentation and representation of a vanished architectural asset. The environment can be used entirely in shared mode with other users, allowing for example, a distance-guided virtual tour. However, the solution doesn't allow to interact with the exhibition elements because the individual institutions copyright the documentary material (Giovannini, 2023a).

Table 2: 'Porta Aurea Hall' SVE project analysis.

Goal	
A virtual exhibition repurposing nowadays layout with content focused on Porta Aurea fragments and historical/archival sources.	
Container Specifications	
***Container* 3D technique**	- Solid modeling from point-cloud of an existing room - materials with reality-based textures
***Container* 3D repository**	- n. 1, 3D model - SketchFab
Type of Content	
1D	**2D** / **3D**
text	x image / x 3D model
audio	video / 360° image
Type of Content Interactions	
1D	**2D** / **3D**
text	image / 3D model
audio	video / 360° image
Content specifications	
***Content* 3D technique**	- Photogrammetric acquisition - retopologization processes - materials with reality-based textures
***Content* 3D repository**	- n. 3, 3D models - SketchFab
***Content* 2D repository**	- n. 10, images - GitHub

Figure 4: Images of the SVE of the 'Porta Aurea Hall' at the National Museum in Ravenna.

4.1.2 *EMEA* Collection at Egyptian Museum in Turin

The 'Expedition Models of Egyptian Architectures' EMEA collection consists of fifteen wooden *maquettes*, part of a collection stored in depots of the Egyptian Museum in Turin. The *maquettes*, dated to the early 1800s, were created to show to the large public the exotic wonders of Egypt and Nubian temples. The collection was investigated from multiple aspects in the funded international project entitled B.A.C.K. TO T.H.E. F.U.T.U.RE.

Part of the project was employed in the photogrammetric acquisition of wooden objects and testing new tools and web-based methodologies for their fruition (Mafrici and Giovannini, 2020). Virtual and immersive environment reconstruction activities also complemented parallel historical research activities. The research also involved the Institute of Heritage Science ISPC-CNR in developing a game that re-proposes the collection in its past configuration in the Egyptian Museum, which is extremely real and immersive (Lo Turco et al., 2020). However, the limitations of the application Unreal Engine do not allow for wide-ranging dissemination, effectively making the activity little known and not usable by the public (Giovannini et al., 2023).

The subsequent experimentation here presented took up the 'experimental' challenge of repurposing the digital assets (container and content) developed for the game at a lower resolution that could, however, make the environment usable through web-based technology using Mozilla Hubs, Spoke, SketchFab, and GitHub (Giovannini, 2023b).

According to historical pictures and documentation, the scene also comprises Sekhmet statues. Near each maquette is the archival documentation (planche) corresponding to the Temple depicted by each wooden model.

Table 3: 'Expedition Models of Egyptian Architectures' SVE project analysis.

Goal			
A virtual exhibition with a historical layout repurposed based on documents and historical/archival sources.			
Container Specifications			
Container **3D technique**	- Solid modeling from CAD of an existing room - no texture/clay visualization		
Container **3D repository**	- n. 1, 3D model - SketchFab		
Type of Content			
1D	**2D**	**3D**	
text	x image	x 3D model	
audio	video	360° image	
Type of Content Interactions			
1D	**2D**	**3D**	
text	x image	3D model	
audio	video	360° image	
Content specifications			
Content **3D technique**	- Photogrammetric acquisition - retopologization processes - materials with reality-based textures		
Content **3D repository**	- n. 13, 3D models - SketchFab		
Content **2D repository**	- n. 10, images - GitHub		

Figure 5: The 'Expedition Models of Egyptian Architectures' of the Egyptian Museum in Turin.

4.1.3 'Phygital Experience' of the Museum Passion in Sordevolo

The SVE experience aims to create the *digital twin* of the temporary exhibition entitled *Phygital Exhibition*. The on-site exhibition was an initiative of the Museum Passion in Sordevolo and opened in July 2022 in the Church of Santa Marta. (Giovannini and Bono, 2023). The exhibition's theme was to narrate the evolution of the set design projects since the late XIX century. The Passion, in the form of Popular theatre, is part of the intangible heritage of Piedmont. The core was to document the intangible heritage through tangible documentation. For creating the environment of the Church (container), solid modeling was used to simulate the real space with a low level of detail while recreating the color of the interior with textures.

Table 4: 'Phygital Experience' SVE project analysis.

Goal			
A virtual exhibition of a temporary exhibition layout repurposing simplified reality. The content of the SVE is different from the actual set-up and is enriched with material that cannot be visualized in reality.			
Container Specifications			
Container **3D technique**	- Solid modeling repurposing the simplified interior of an existing church - materials with generic textures		
Container **3D repository**	- n. 1, 3D model - SketchFab		
Type of Content			
1D	**2D**	**3D**	
x text	x image	x 3D model	
audio	x video	x 360° image	
Type of Content Interactions			
1D	**2D**	**3D**	
text	x image	3D model	
audio	x video	x 360° image	
Content specifications			
Content **3D technique**	- Photogrammetric acquisition of current set design and a maquette - retopologization processes - materials with reality-based textures		
	- Solid modeling repurposing simplified reality of past set design - no texture/clay visualization		
Content **3D repository**	- n. 6, 3D models - n. 1, 360° image - SketchFab		
Content **2D repository**	- n. 11 videos - YouTube		
	- n. 15, images - GitHub		
Content **1D repository**	- n. 30, textual elements (Spoke elements)		

The collection (content) composed of panels and infographics was re-proposed in the digital environment, allowing interaction with each image. The church's side chapels were used to store 3D models, historical videos, and a 360° immersive picture where it is possible to enter and visualize it as a 360° virtual tour. The other perimeter walls were also used to collect a digital gallery of more recent videos already stored in the YouTube channel of the Museum Passion. The main empty wall in the Presbyterian area carries the video with 3D animations developed during a previous collaboration between the Department of Architecture and Design DAD of Politecnico di Torino and the Museum Passion (Giovannini et al., 2021).

Figure 6: The 'Phygital Experience' of the Museum Passion in Sordevolo.

4.2 Didactic Activities in Architecture

The following three experiences fall within the scope of the dissemination of teaching activity carried out both at the level of master's degree programs and as a circumscribed activity of a master thesis still in progress.

The intention to create immersive and social environments to collect student works and their two- and three-dimensional outcomes aligns with the *Telearchitettura* (TA) portal's primary mission. TA is an online platform of the Department of Architecture and Design DAD and it is part of the *Center for Education in Architecture* activities. The platform collects the outcomes of all degree courses afferent to DAD by creating individual web pages dedicated to courses, seminars, and ateliers. The activity of collecting student outcomes originated during the COVID-19 pandemic, and the platform was configured as a tool to collect not only student 2D layouts but also videos to maintain the memory of revisions in a participatory dialogue between students and faculty members.

The discipline of drawing and representation thus set itself the ambition of overcoming the two-dimensionality of web pages, where content is collected in the form of images, videos, and texts, by adding the third dimension. This action is also aligned with many other latest universities' experiences.

In 2018, 2020, and 2021, Tulane University developed a digital recreation of Tulane School of Architecture's large lecture hall as a virtual exhibition experience to showcase Thesis projects by Graduate and Undergraduate students. (Tulane, University, n.a.) *The Uncertain Space* is the Virtual Museum of the University of Bristol in the UK. (University of Bristol Museum, n.a.) Harward University with *Archiverse* created a digital design platform for architectural and artistic creation using a collaborative VR environment. (Harvard University, n.a.) The TU Delft organized the VR exhibition *The News of the Progress 2.0*, collecting the graduate work of Architectural Engineering students. (Starink, 2020) In 2021, Newcastle University's School of Architecture and Planning launched the *Virtual Degree Show* (V21 ArtSpace, 2021). The XR Lab at UC Berkeley launched the *Virtual Bauer Wurster*, where students can upload their drawings and 3D models and interact with others (Natividad, 2021).

Within this panorama, Social Virtual Environments have played and are still playing an undoubtedly significant role on the teaching front (Poolsawas, 2023; Cowie, 2022).

4.2.1 The *Inside the Museum* Seminar

The first prototype experience was created in 2023 for the introductory seminar *Inside the Museum*, in which the disciplines of digital design representation collaborate with Exhibit Design and Museography. Students develop a design proposal to be implemented inside a museum space. The activity also requires students to use Extended Reality tools within the exhibit and narrate the design projects for the exhibit itself.

In 2023, the introductory seminar aimed to develop an exhibition design for the *FIAT Lingotto* in Turin. As part of the course activities, an on-site temporary exhibition was developed to show students' outcomes to the future student community at Valentino Castle, inside the '*Sala delle Colonne*.'

The space is commonly used for exhibitions and various events, and it consists of a hall with six columns and a vaulted system. The aim of recreating the space in a virtual exhibition was to document the

on-site temporary exhibition, creating a diverse access point for students' outcomes.

A photogrammetric acquisition was made to develop the digital space (container) to obtain 3D textured meshes of specific elements: columns and stucco decorations. The intention was to close the gap between real space and its digital replica. The 3D model of the hall was used as a 3D environment (container) with the possibility to interact with its elements (content): students' layouts, 3D models, videos, and audio tracks obtained from a voice synthesizer (Giovannini et al., 2023b).

Table 5: The 'Inside the Museum Experience' SVE project analysis.

Goal	
A virtual exhibition of a temporary exhibition layout repurposing simplified reality. The content of the SVE is different from the original set-up. It is enriched with students' material that cannot be visualized in reality, including videos and audio tracks narrating the concept of each project.	
Container Specifications	
Container **3D technique**	- Solid modeling from point-cloud of an existing room - colored texture materials
	- Photogrammetric acquisition of architectural elements that characterize the space - retopologization processes - materials with reality-based textures
Container **3D repository**	- n. 2, 3D model - SketchFab

Type of Content		
1D	**2D**	**3D**
x text	x image	x 3D model
x audio	x video	360° image

Type of Content Interactions		
1D	**2D**	**3D**
text	x image	3D model
x audio	x video	360° image

Content specifications	
Content **3D technique**	- Solid modeling repurposing maquette and exhibition panels - no texture/clay visualization
Content **3D repository**	- n. 6, 3D models - SketchFab
Content **2D repository**	- n. 15, images - GitHub
	- n. 5 videos - YouTube
Content **1D repository**	- n. 16, textual elements (Spoke elements) - n. 16 audio tracks

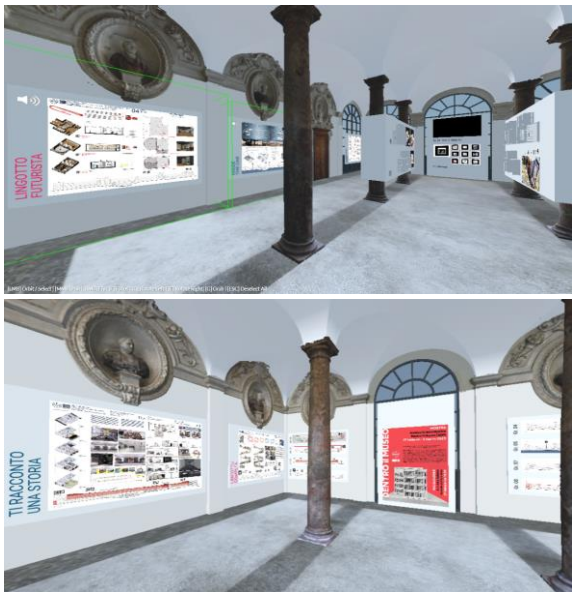


Figure 7: The 'Inside the Museum Experience' for the Telearchitettura platform at Politecnico di Torino is on the top audio frame.

The prototyped environment was embedded in the Telearchitettura portal that already contain other course information.

In 2024, the seminar activity was replicated. The case study was the design exhibit for '*Sale Auliche*' at the Reale Mutua Historical Museum in Turin. The exhibit comprises five rooms with painted vaults and coffered ceilings. Silk wallpapers and diverse door and window ornaments also characterized all the rooms. Again, the photographic and photogrammetric acquisition was done to obtain reality-based textures for the 3D scene (container). This environment differs from the previous one because it aims to develop a guided virtual exhibition using five rooms as it happens in reality.

The scene was then quite complex to optimize, and it collects both reality-based 3D models for vaulted systems and low-poly 3D models used for walls. The 'content' consists of diverse types of student outcomes. The seminar's didactic activities also comprise developing different extended reality solutions, including digital replicas, of their proposed exhibition layouts.

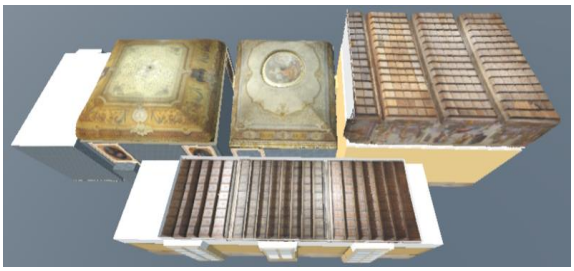


Figure 8: The 'container' 3D digital asset of '*Sale Auliche* Experience' for Reale Mutua Historical Museum in Turin.

Table 6: '*Sale Auliche* Experience' SVE project analysis.

Goal	
A virtual exhibition of a temporary exhibition layout repurposing simplified reality. The content of the SVE is different from the actual setup and is enriched with exhibition layouts proposed by course students.	
Container Specifications	
***Container* 3D technique**	- Solid modeling from CAD - materials with reality-based textures
	- Photogrammetric acquisition of architectural elements that characterize the space (ceilings and vaulted systems) - retopologization processes - materials with reality-based textures
***Container* 3D repository**	- n. 9, 3D model - SketchFab
Type of Content	
1D	**2D** / **3D**
text	x image / x 3D model
audio	x video / x 360° image
Type of Content Interactions	
1D	**2D** / **3D**
text	x image / 3D model
audio	x video / x 360° image
Content specifications	
***Content* 3D technique**	- Solid modeling repurposing maquette and exhibition panels - no texture/clay visualization
	- 360° images used as primary access to virtual tours developed by students
***Content* 3D repository**	- n. 2, 3D models - n. 18, 360° image - SketchFab
***Content* 2D repository**	- n. 40, images - GitHub
	- n. 18 videos - YouTube
***Content* 1D repository**	- n. 55, textual elements (Spoke elements)

Figure 9: The 'container' 3D model of '*Sale Auliche* Experience' for Reale Mutua Historical Museum in Turin with an exhibit solution developed by a student group.

Figure 10: The 'container' 3D model of '*Sale Auliche* Experience' for Reale Mutua Historical Museum in Turin with an exhibit solution developed by a student group.

4.2.2 *TeleArchitettura* Virtual Space

Table 7: '*TeleArchitettura* Virtual' SVE project analysis.

Goal		
A virtual portal to access *TeleArchitettura* platform content.		
Container Specifications		
***Container* 3D technique**	- Solid modeling - no texture/colored visualization	
***Container* 3D repository**	- n. 9, 3D model - SketchFab	
Type of Content		
1D	**2D**	**3D**
text	**x** image	**x** 3D model
audio	video	360° image
Type of Content Interactions		
1D	**2D**	**3D**
text	**x** image	3D model
audio	video	360° image
Content specifications		
***Content* 3D technique**	- Photogrammetric acquisition - retopologization processes - materials with reality-based textures	
***Content* 3D repository**	- 3D models (according to courses groups and materials available) - SketchFab	
***Content* 2D repository**	- images (according to courses groups and materials available) - GitHub	

TeleArchitettura is an institutional web platform that collects didactic activities of academic courses for bachelor's and master's degrees. Creating the digital assets for the virtual environment follows the idea of creating a TeleArchitettura virtual space where student works can be exhibited, and the content can be visualized and scrolled in an immersive way using VR headsets. Extended reality applications are also part of student work and can enrich the digital space, augmenting the diversity of possible virtual interactions.

The space's design concept follows the idea of creating spaces according to the type of interaction with specific digital contents: 1D, 2D, or 3D. The space consists of a series of hub rooms connected by portals that allow one to pass from one space to another.

The main Hall introduces the diverse degree courses offered by DAD. Each degree course is then subdivided according to academic courses, organized by academic years, and shows students' outcomes or, eventually, registered plenary reviews. A gallery also comprises the newest added content to the platform.

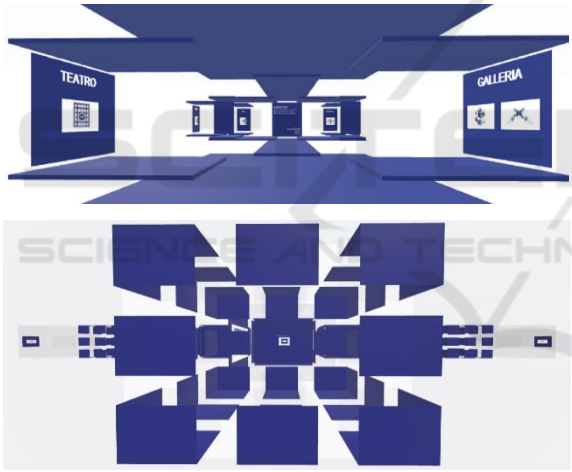


Figure 11: The '*Telearchitettura* Virtual Space' prototype for the main Hall and Gallery developed by P. Cardone.

5 CONCLUSIONS

The paper presents a possible workflows for disseminating cultural heritage and didactic activities using digital technologies and developing digital assets. Integrating and re-elaborating digital assets was also part of the processes to create a comprehensive visualization of content created to be re-used also in diverse context with different storytelling purposes. Within the digital environment, documentary heritage and 3D models can be used the same way as students' outcomes, which generally produce bidimensional layouts and 3D models of their designed projects.

Digital spaces and metaverses have become a way to communicate culture and design projects and a place of interaction for students and professors, the same as museum professionals and visitors. In line with other worldwide extended reality experiences, using web-based Social Virtual Environments to display content can be a good compromise between low cost and ease of development. The outcomes of the activities developed with museum collections, already presented to the public through virtual exhibitions and demo sessions on conference presentations, can also become an asset to populate the virtual display of other alternative virtual exhibitions. Again, *TeleArchitettura* is a space of communication that today uses diverse media, images, and videos. With this experience, the platform will also include digital environments exploring novel ways of communication and interaction between students, academics and large public.

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