Integration of Digital Repositories and Spatial Design within the Metaverse: the Evaluation of Features and Narratives to set Learning Environments on Cultural Heritage

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Abstract

The Metaverse is rapidly advancing across cultural, professional, and service sectors, enhancing data compatibility and interaction. Its architectural design supports both visual interaction and information layers, characterising an ideal platform for the promotion of Digital Heritage. The digitisation of Cultural Heritage and the creation of Digital Repositories find complementarity in the Metaverse, which enables social interactions between Digital Heritage contents and virtual communities. This integration is pivotal for developing Learning Environments, where accessible virtual products can be combined with original digital storytelling and narratives.
The paper presents methods and results from an Erasmus+ international school, which focused on using digital communication and 3D modelling tools to create immersive narratives on Mediterranean architectural modernity. Students from various Cultural Heritage disciplines designed virtual exhibitions within the Metaverse platform *Spatial* and open repository materials. The research concentrated on the application of Metaverse platforms for their spatial design and educational utility within the Heritage sector. The activities included developing digital narratives and interactive exhibitions enriched with multimedia data from digital repositories. The study discusses the limitations of customising visual materials, the importance of repository connections, user experience design, and the potential for future developments in Metaverse applications for Cultural Heritage learning environments and storytelling.

1. Introduction

The field of Cultural Heritage is increasingly taking part in the research perspectives linked to the mission of the Metaverse. The transition to Digital Heritage has been underway for decades, driven by emerging considerations of accessibility, fruition, and preservation of tangible and intangible heritage within opportunities of digital transposition and archiving (Burkey, 2022). Thus, scientific research has concentrated on studying methodologies for both the visualisation and interaction of physical heritage and information contents in the intangible dimension of Digital Twins (Ott and Pozzi, 2010; Paladini et al., 2019). It has resulted in a multiplicity of digital data and virtual products, especially 3D point clouds and virtual models, produced by specialised research in digital documentation and surveys with exponential technical improvement. The application of digitisation workflows (Balletti and Ballarin, 2019) is becoming increasingly efficient, expeditious and multi-instrumental, especially relating to the use of 3D photogrammetry as a fast, low cost and accessible methodology for the production of reality-based virtual models. At the same time, platforms and online repositories are expanding and affirming a standard for the collection and open access to such digital data (Champion and Rahaman, 2020). They are combining archiving and fruition to options for the management and traceability of digital data, expanding the modalities of interaction and association to multiple dimensions of information and research (King et al., 2016; Champion and Rahaman, 2019). For these purposes, the Digitisation of Cultural Heritage and the consequent production of repositories of its digital products can find an “indigenous” complementarity in the application through the Metaverse. Formats and languages, both digitally and ontologically, are natively compatible. Furthermore, advanced social interactions can be established between the “contents” (Digital Heritage data) and the wider community of virtual users through the “container” (Metaverse) (Tlili et al., 2022; Al-Tabeeb and Al-Desouqi, 2023).
The scientific relevance is highlighted in the advancement of Learning Environments from Digital Heritage (Gaafar, 2021; Lee, 2023): the availability and accessibility of heritage virtual products (Chong et al., 2021; Parrinello and De Marco, 2022) in the web space can be combined with the design of digital narratives and story-telling collections, taking advantage of the Metaverse dimension (Cruz et al., 2022; Gonçalves et al., 2022). Cultural storytelling through the tools of Virtual Reality can be adopted in different declinations, experimenting with the types of interactions between the users and the storyteller (Buhalis and Karatay, 2022), who also can be the designer of the narrative space. In this case, an accessible workflow of spatial design and management of 3D virtual artefacts has to be considered.

2. Background

To contextualise the scientific discourse of integration between Metaverse and Digital Repositories, it is important to outline a background of how these applications are currently developed and used concerning Cultural Heritage digital contents and formats. Furthermore, ongoing examples of how museums and cultural organisations are experimenting with their adoption into proper facilities are central to understanding the potential of development and the aims of the scientific debate.

2.1 Digital Repositories for Cultural Heritage

The practice of digitising Cultural Heritage artefacts, at different scales and different sectors, has focused on how to organise and preserve such materials from a perspective of sustainability, accessibility, and reapplication of data. Digital Repositories have assumed the value of proper “libraries”, developing codes and instructions for “cataloguing” such materials, adopting metadata,

and working even more on accessibility and interaction tools for users towards the same archive and through third platforms.
Compared to initial versions, repositories have progressively evolved in the characteristics of Web 3.0 (3D and semantic web) and Web 4.0 (compatible with Extended Reality and real-time interaction for the digital *alter ego*) (Ghani et al., 2020). From a critical analysis of online repositories (Champion and Rahaman, 2020), it is possible to observe the characteristics and interaction properties that are offered for Digital Heritage concerning the type of parties/actions entrusted with the main development of the repository and the offered type of data formats. In some cases, the repository is limited to the interactive use of data, offered as virtual tours or spot information (e.g., *CyArk*, *Smithsonian 3D* and other public/private museums). Otherwise, options are offered to the user to customise the use of data, creating at the same time original and creative sub-themes for the educational and cataloguing enrichment of the repository provider (e.g., *Europeana* and its building tool for “Galleries”) (Fig. 1) (Giannakoulopoulos et al., 2021; Macrì and Cristofaro, 2021).

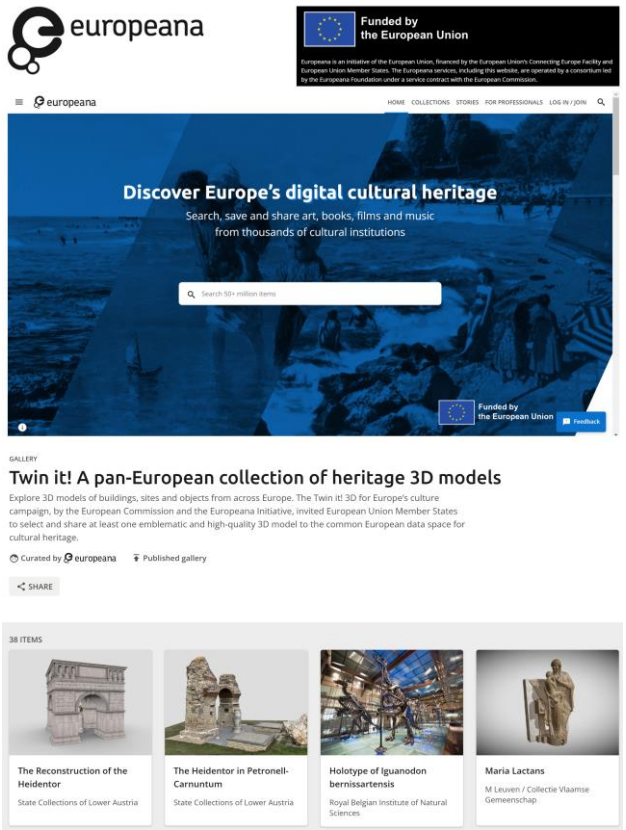

Figure 1. *Europeana* platform, with a Gallery dedicated to 3D models for Cultural Heritage (“*Twin it! 3D for Europe’s culture campaign*”, European Commission and Europeana, 2023).

Furthermore, there is the case of repositories built through the provision of services and the construction of communities that performed proper crowdsourcing actions in populating the repository itself (e.g., *Sketchfab*, *3DHOP*). In this case, the service platform generated the construction of the repository at the same time as the service application by the clients, who are primarily in charge of generating, uploading, and implementing Digital Heritage products and their metadata. The platform is responsible for supervising and indexing the uploaded data, guaranteeing not only a private service but also a public impact and value to the web community in the construction of the branded “gallery”. In this role of supervision, FAIR guiding principles for data management and R4 goals (Re-usable, Relevant, Reliable and Resilient) direct the creation of formats of descriptive metadata for digital resources (Fig. 2) (Sotirova-Valkova, 2020; Barbuti, 2021).

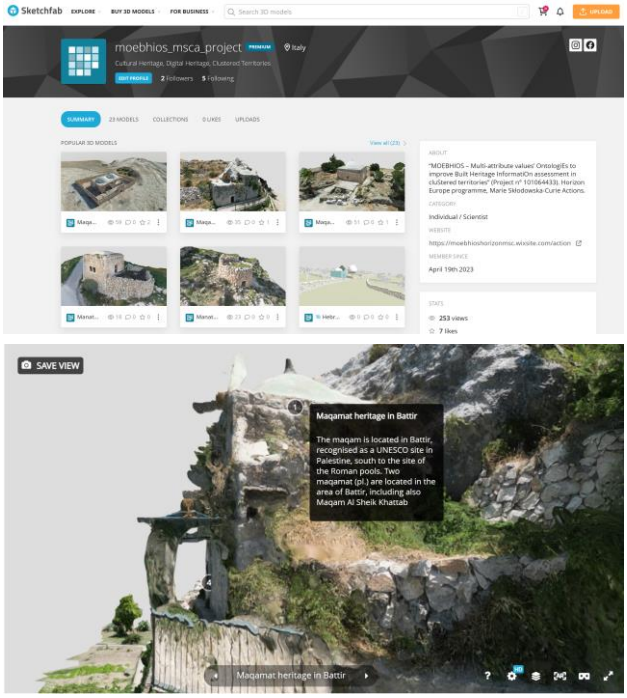

Figure 2. *SketchFab* platform, with 3D interactive virtual models, geometric quality and information implementation to promote indexing and reuse of the data (“MOEBHIOS” Horizon Europe project, MSCA Fellowship, 2022).

Thus, it activates a continuous mechanism of enrichment of these repositories, which through the service brand also remain up to date in terms of the quality of the digital data and its adaptability to the virtuality and interactivity of the growing web platforms, finalised by the Metaverse landscape.

2.2 Metaverse development towards Learning purposes

The empowerment of Metaverse is proceeding exponentially, interesting multiple cultural, professional, and service spheres. In addition to the main core of Gaming function (e.g., *Core Game*, *Zepeto*, *Fortnite*, *Rec Room*, *Sinespace*, *Avakin Life*), a second main application of Virtual Interaction is highlighted in the core platforms aimed at the virtual socialisation of community users (e.g., *Vesta*, *Sansar*, *Stageverse*, *Open Simulator*, *Gaia Online*, *Spatial*). Other platforms showed more specific declinations to cater for a defined and sectorial niche audience (e.g., *Wave* for virtual concert events entirely hosted in the Metaverse, *Wooz World* and *Imvu* for fashion and styling business virtual events).
According to the main function assumed by the Metaverse platform, the possibilities of compatibility and interaction of different formats of data are expanding the characterisations of its “architectural design” (Duan et al., 2021). It involves the attention to practicable solutions both in the visual “interaction” layers of the Metaverse environment and in the sub-present “information” layers of metadata and ontologies, even externally referenced. It is suitable to connect the Metaverse application to the concept of Virtual Learning Environments, as virtual spaces for learning, interaction and consultation of educational contents, exchange of information and sharing of materials. They are meant for the creation and management of a more effective

learning ecosystem based on digital tools and interactions for personalised supervision of educational time and users’ attitudes, in this case regarding Cultural Heritage (Ibrahim and Ali, 2018; Megan et al., 2021; Parrinello and De Marco, 2022).
From a technical point of view of platform implementation by creators, the approach to the Metaverse increasingly follows interfaces common to web design. At the same time, specific design in increasingly defined “architectural terms” of the simulated space is implied, especially when the main function is assumed related to the educational sphere (Tlili et al., 2022). To facilitate the human perception of the user for location and orientation as background to learning attention in the virtual space, Metaverse environments originate fundamentally from “mirror worlds”, inspired by cultural social virtual environments such as museums and exhibitions (Giovannini, 2024). Within them, alterations are made possible by the Extended Reality format, as spatial paradoxes, and augmented dimensions of information between users, space and contents.

2.3 Metaverse adoption in the educational/cultural sector

Museums and exhibition services are increasingly interested in their service development in the Metaverse, in the perspective of the digital transition of their collections and in developing a new attraction of the public to creative exhibition themes and media, especially through tools of Web 4.0 (Lu et al., 2023; Longo and Faraci, 2023). A cultural theme can be declined in a playful dimension of an immersive and interacting virtual environment, as the re-imagination of a narrative story (*Curious Alice: the VR experience*, 2021, Victoria & Albert Museum). As well, it can also be developed concisely and interactively through “modular spaces” for 3D immersive exhibitions (*Pocket Galleries*, Google Arts & Culture, 2021) (Fig. 3).

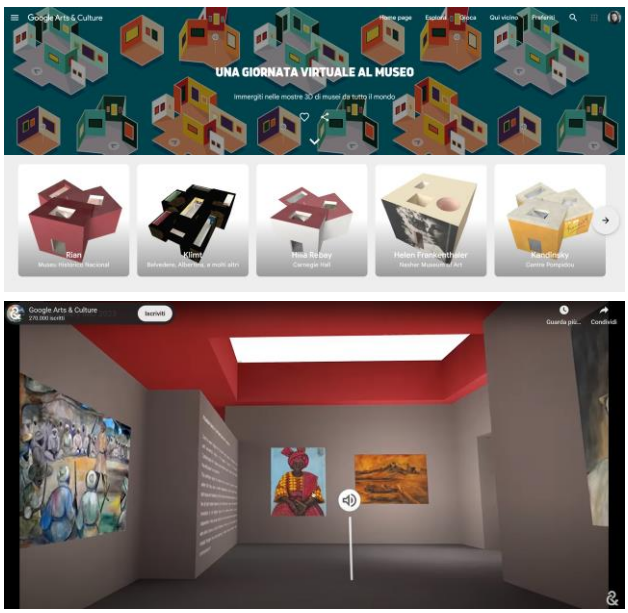

Figure 3. *Google Pocket Galleries*, interaction and cultural narratives in 3D spatial storytelling (Google Arts & Culture, https://artsandculture.google.com/project/pocket-gallery).

The dimensions of impact envisaged by museum institutions are multiple and developed both in terms of audience and narrative characterisation. The potential of reaching a global audience has an impact in terms of accessibility, resolving both geographical and physical constraints. The interactivity offered by the Metaverse also allows visitors to play a crucial role in a new perspective of Cultural Heritage preservation, allowing them to interact with content not just passively but by leaving their active contribution in the form of quests, questionnaires, or other collaborative information release. At the same time, users are encouraged to participate by receiving virtual content as a free reward in return (Xia et al., 2023).
The MET Metropolitan Museum of Art (New York, 2023) has set up *MET's Replica* system, which through an app offers a Learning Environment based on the discovery-reward system, imitating the basic principle of gaming. Jake Vordun with its *Vordun Museum & Gallery* (2016) provides on *Second Life* a digital replica of exhibits with dynamic settings, and the British Museum, in partnership with the Metaverse platform *The Sandbox*, has anticipated a service to enrich educational opportunities and provide history and culture with a brand-new way to engage with the museum’s collections (London, 2024). Furthermore, interactivity and engagement are highlighted in *NABIYA unveiled Maison NABI Haetera* by the Musée des Tissus & les arts décoratifs of Lyon (2023), structured as an online gamified experience of silk-making art.

2.4 Aims and Objectives

As the demand for digital services is growing in the cultural sector, it becomes central to work facing a related search for resources and expertise to establish a robust digital presence of cultural institutions and content in the Metaverse, relying on expertise and professionals. An opportunity is considered to include these topics in the didactic and research experience of transversal fields from Cultural Heritage education. At the same time, a limitation is seen in the demand for technical skills in modelling and management of virtual environments, which are specific to some curricula such as engineering and architecture but unfamiliar in the social sciences and the fields of landscape, tourism, museum management and cultural heritage policy.
The research framework aimed to evaluate a workflow for the design and management of exhibition/museum models as Learning Environments in the Metaverse, considering in parallel both the suitability of the platform to host this type of project and the extent of the digital languages required for its programming. The objective pursued was to test through a didactic activity the familiarity of students from both humanistic and technical disciplines with the Metaverse landscape, and to push them to translate their knowledge of design for Cultural Heritage narratives into the terms of a virtual and interactive dimension.
Preliminary to the didactic experimentation, scientific research included a critical analysis of the main Metaverse platforms, identifying features and requirements available to enhance its cultural application, user experience and programming language. The analysis was aimed at reviewing the present-day applicability of Metaverse platforms to the non-strictly entertainment function, such as the design of Learning Environments from the educational perspective. and selecting the pilot environment for experimentation.

3. Materials and Methods

The paper presents the methods and results developed through an international Summer School co-funded by the Erasmus+ programme. It was addressed for adopting didactic tools of digital communication and modelling practices of immersive 3D scenarios for the narration of cultural multimedia content on the Mediterranean heritage of Architectural Modernity. The activities experimented with a didactic opportunity to allow students from different fields related to Cultural Heritage (architecture, engineering, landscape, arts, history, economics) to develop the basis of a Learning Environment in the Metaverse,

selecting a narrative topic and designing a virtual interactive exhibition, also with the support of data from open repositories.
The research experience was developed in two phases. Phase 1: preliminary research for assessing the state-of-the-art of the most available Metaverse platforms, and evaluating their features of spatial design and user experience concerning educational purposes and didactic experience. Phase 2: practical didactic activity with students, as an international workshop structured on theoretical lectures and laboratory tasks, aimed at the development of digital narratives and Learning Environments from the analysis of Modernity in Architecture across the Mediterranean.

3.1 Architecture of the Metaverse platform: analysis and features evaluation for Cultural Heritage experience

In Phase 1, a critical analysis of the main Metaverse platforms was conducted, starting with those mentioned by the Metaverse Observatory in its *Map of the Metaverse* (2022). An existing classification of Metaverse by the seven layers has already been addressed (Infrastructure, Human Interface, Decentralisation, Spatial Computing, Creator Economy, Discovery, and Experience) (Wang et al., 2022). However, the present research has introduced novel key points, defined as *features*, in the perspective of the application of the Metaverse technology to the development of Learning Virtual Environments in the sector of Cultural Heritage.
Metaverse Environments have been compared by establishing a list of key features considered central for (i) applying the design of the Metaverse to the cultural/educational narrative function; (ii) working in synergy and sustainability of the use of open repositories of digital material on Cultural Heritage; (iii) adopting no-specialised options and tools for managing the design component of the environment and user interactions; (iv) making the generation and management of the system available for users from not only technical sectors related to Cultural Heritage.
The features evaluated in the critical analysis concerned this list.

Core function: specific functional scope of the platforms. Predominantly they are divided into two functions, Gaming (e.g. *Core Games*, *Zepeto*, *Fortnite*, *Avakin Life*) and Virtual Interaction (e.g. *Mozilla Hubs*, *Vesta*, *Sansar*, *Spatial*), in some cases in a mixed format. Other platforms highlight specific and branded functional particularities, such as *Wave* or *Stageverse* for hosting virtual concerts, or *Wooz World* for fashion events and exhibitions. In the research aim, platforms dedicated to Virtual Interaction have been preferred to pursue the objectives of designing Learning Environments and cultural narratives.

Cultural adoption: declination of the platforms to environments and/or content from the cultural sector. The evaluation was conducted by considering existing examples, where the content and modalities of navigation and interaction demonstrated a dedicated focus on the educational and cultural experience. Some platforms showed experiences already implemented and open to the public (e.g., *Mozilla Hubs*, *Sansar*, *Stageverse*, *Cluster*, *Minecraft*, *Spatial*).

Interaction with Cultural Heritage Open Repositories: predisposition of the platforms to interconnect with Open Repositories on the web, dedicated to Cultural Heritage content. This feature was traced in just a few cases from the platforms list, in particular for *Mozilla Hubs* and *Spatial*, and in both cases, it regarded compatibility with the *SketchFab* platform.

Data/Multimedia Integration: it was assessed the feasibility of inserting external data and multimedia (images, GIFs, videos), also from web sources (e.g. *YouTube*), into the platform and integrating them into the design of the virtual environment as interactive content, suitable into the designed narrative path. External links, both display-only and questionnaires, were also considered. Only a few platforms showed this compatibility (e.g., *Mozilla Hubs*, *Stageverse*, *Sinespace*, *Spatial*).

Social Interaction: this feature assessed the quality of interaction of virtual users both concerning the contents of the environment and other users engaged in the same visit. The possibility of interacting with other users to exchange impressions, opinions, and dialogues, especially in real-time, towards the same experience of information or visibility of cultural artefact was considered. The opportunity to leave comments and information beyond the time of the visit was considered, but in this case, it was classified in the previous category in terms of data integration with respect to the native Metaverse environment. As the main quality of the Metaverse's technology, all the analysed environments presented optimal conditions for this feature.

Metaverse Environment	Core Function	Cultural adoption	Interaction CH Open Repositories	Data/Multimedia Integration	Social Interaction	Spatial Design facility	Software requirement	Advance Scripting
CORE GAMES	Gaming				X	X	X	
ZEPETO	Gaming				X		X	
HUBS MOZILLA	Virtual Interactions	X	X	All	X	X		X
VESTA	Virtual Interactions				X		X	X
SANSAR	Virtual Interactions	X			X	X	X	X
FORTNITE	Gaming				X		X	
HIBERWORLD	Gaming/Virtual Int.				X	X (limited)		
STAGEVERSE	Specific (virtual concerts)	X		Images, Gif, video	X	X (limited)		
CLUSTER	Gaming/Virtual Int.	X			X	X	X	X
REC ROOM	Gaming	X			X	X	X	
WAVE	Specific (virtual concerts)	-	-	-	-	-	-	-
SINESPACE	Gaming/Virtual Int.			Images, Videos	X	X	X	X
AVAKIN LIFE	Gaming				X		X	
WOOZ WORLD	Specific (Fashionistas)	-	-	-	-	-	-	-
MINECRAFT	Virtual Interactions	X			X	X	X	
OPEN SIMULATOR	Virtual Interactions				X	X	X	X
ROBLOX	Gaming/Virtual Int.	X			X		X	
IMVU	Specific (Styling business)	-	-	-	-	-	-	-
GAIA ONLINE	Virtual Interaction				X			
SPATIAL	**Virtual Interactions**	**X**	**X**	**X**	**X**	**X**		

Figure 4. Critical analysis of the main Metaverse platforms considering key features selected for the objective of designing of social immersive environments for cultural narratives and interactive Learning Environments (Images developed by the Autor).

Spatial Design facility: this feature analyses how the 3D space hosting the educational environment in the Metaverse is created and managed. Several qualities were evaluated, such as the provision of starting by adopting spatial templates, the modelling of the 3D space directly via the web and not through external platforms; the virtual ‘physical’ limitations to the setting up of architectural and exhibition components for the spatial design; the formats and design sets available for the digital learning contents and materials; the availability of abacuses and galleries of furniture elements or the connection to external galleries for their use. Not all the Metaverse platforms analysed have shown compatibility, and among those available, some showed extreme limitations to the qualitative design of virtual space. Among the most suitable were *Mozilla Hubs, Sansar, Cluster, Sinespace, Spatial* and *Open Simulator*.

Software requirement: this feature assessed the need for installing software components for the design of the Metaverse environment, or the possibility of working directly with the hard drive on the online platform, in stand-alone mode, without added components. This feature is relevant to allow the workflow to be accessible to non-professional users in 3D modelling and virtual reality, and it also facilitates hard drive use and training tasks, just relying on the web connection band. Few Metaverse platforms have proven to be able to operate in web stand-alone mode, e.g. *Mozilla Hubs, Stageverse, Gaia Online and Spatial*.

Advanced Scripting: also, this feature assessed the need for advanced computer language and programming skills to be able to operate in the virtual environment and contents management. It was highlighted that at least half of the Metaverse platforms require such skills, which are uncommon in several academic and professional fields related to Cultural Heritage. Advanced scripting is not fundamentally required in e.g. *Hiberworld, Stageverse, Roblox, Gaia Online*, and *Spatial*.

From the following considerations (Fig. 4), the environment of *Spatial* (Metaverse, 2016) has been evaluated as the feasible and adaptable choice to be applied for the didactic experimentation.

3.2 Design of Learning Environments in the Metaverse: Heritage scenarios and practical tools

Phase 2 included the workshop activities of the International Summer School, conducted in September 2023. The school aimed to encourage students to research original ideas of storytelling about Modernity in Architecture. They could also take advantage of their multi-national background (Italy, Portugal, Germany, Palestine, Ukraine, Serbia) to build a wider dialogue and comparison of knowledge and case studies.
Theoretical lectures on architectural archiving and analysis, digital data on Cultural Heritage, Metaverse applications, Cultural Heritage values, promotion and communication were introduced. Then, the participants followed the laboratory sessions and applied their knowledge to the design of a shared virtual environment, setting the space in *Spatial* and using original data or open access contents from *SketchFab* gallery.

Spatial platform offers free starting templates of 3D spatial assets already disposed of interactive tools, some already designed in the format of exhibition galleries or museum spaces. The assets have a preset disposition of 2D panels for content insertion. Furthermore, it is possible to implement them or to create new spaces through a more advanced modelling toolkit, operating through compatibility with the *Unity* platform and C# language.
The design of the scene takes place in web-based online mode, navigating in real-time in the virtual space through a personal avatar, and activating a camera with both subjective and external views (Fig. 5). Among the platform collaborative opportunities, there is the possibility of creating and managing teams between users, who can be logged in simultaneously in real-time in the same spatial asset and operate at the same time in the management, editing and setting up of content and options. Autosave is enabled by the platform, with a synchronous modality between the different editing users connected.

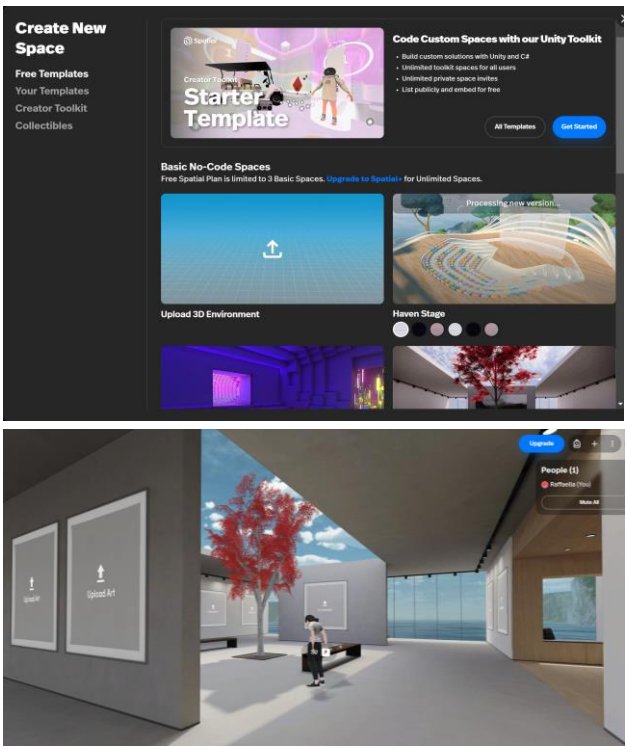

Figure 5. Spatial platform: spatial templates and starting asset.

The ‘Content’ input tool introduces the categories of materials and data that can be set up in the virtual environment, with standard galleries of ‘Stuff’ and ‘Supplies’ and a direct link to *Sketchfab* via user login. Similarly, NFTs and other models’ templates or upload materials can be activated and imported, also synchronised by Google Drive.
The insertion of an artefact from *SketchFab* highlights two sets of properties: the possibility to move, rotate and scale the object in the virtual space (‘spatial control’) and the availability of an information label that keeps the artefact uniquely connected with the proprietary information from its location in *SketchFab* (‘metadata control’). This tool expresses utility and quality in promoting the FAIR guidelines of digital data use (Fig. 6).
In addition to 3D models, it is possible to insert multimedia material, either by exploiting surface content ‘panels’, arranged on the walls, or by creating new ones and applying them within the scene. Design solutions can either be tracing the surfaces or adopting them as new design components of the virtual space. Images, cached videos, or videos from the web (e.g. *YouTube*) can be loaded onto these formats. Images are also adaptable in terms of QR codes or interactive links, associated with personal labels, to connect tools of interactive participation or survey.
As interaction functions, Spatial offers both standard ‘emoticons’ and avatar reactions, as well as the ability to interact directly via chat or microphone and camera controls or to produce interactive experience content with Filming tools. The virtual environment can be shared through links, managing user or visitor roles, and using the ‘Live’ Highlight to connect broadly to the *Spatial* community and be promoted through the platform.

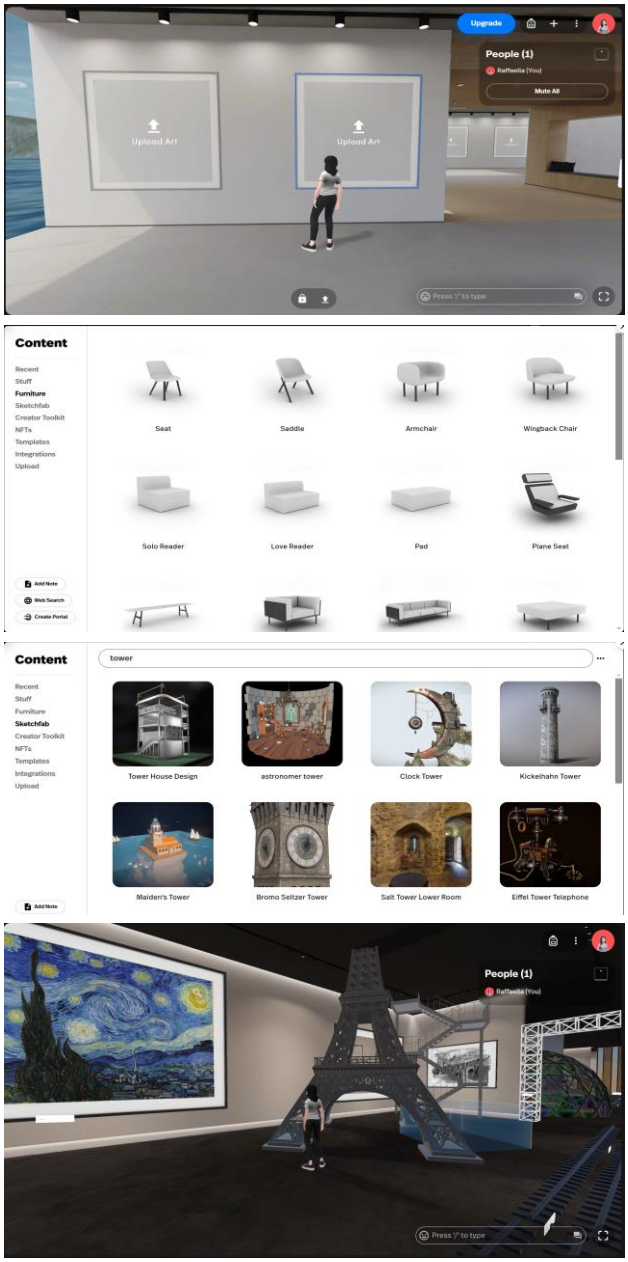

Figure 6. Tools, assets, and galleries for the spatial design in *Spatial* platform of Metaverse experience

4. Results

During the activities of the International Summer School, the participating students worked in mixed international groups, designing 8 virtual environments on the *Spatial* platform. From the assumption of a thematic path and an assessment of heritage values for the communication aim, they were responsible for the insertion of content and for the management of the interactive experience, with the aim of producing original cultural narratives on topics related to Architectural Modernity.

The use of 3D components, images, and videos, coming from a systematic action of analysis and use of archives and databases, and the design properties of the virtual space made it possible to work on the objective of both the thematic information shared and the virtual user experience. It enabled the construction of 360° immersive learning environments that also involved the design of sensations and perceptions experienced during the virtual visit, calibrating sounds and lighting of the environment.

Selected themes developed comparisons across countries and cultures, such as between Ukraine, Italy, and Palestine on the endangered heritage, or between Palestine, Egypt, and Portugal in the influence of modern style between broader architects. Other projects have experimented with the ‘mirror-space’ reproduction of famous architectural environments from Modernity, while developing the multidimensional opportunity of the virtual platform to convert architecture beyond three dimensions and introduce alternative information content and visiting paradoxes to the physical experience, such as mazes or hidden doors.

The adoption of gallery elements made it possible to work not only on the educational content of the visit. It also allowed to combine the original design of the virtual spaces, denying physical constraints, with impossible and therefore unprecedented solutions for setting up and communicating the cultural content. Some spatial environments have been designed with projection sections, playing on the possibility of avoiding sitting spaces or crowding users, who in the virtual paradox don’t need more time and effort to visit than the real visitor placed in front of the remote device. Other sections were transformed from interiors to exteriors, adding a more complex design of virtual content and activity rooms, where the virtual user can be both a spectator and actor of the scene, in a public relation with the virtual community.

The results and virtual environments are presented in Fig. 7 and can be visited directly through the associated QR codes. The use from a smartphone or tablet device involves an internet connection and the installation of a supporting app to conduct the immersive visit, automatically relinked from the device.

5. Conclusions

Considerations are conducted from the discussion on the results and the future assessment of impact and feedback from the Learning Environments integration and experience. In this way, it provides the basis for developing a debate on the future opportunities of research and the next developments of the Metaverse environments for the implementation of cultural narratives and educational purposes in Cultural Heritage. The main points of debate are the followings.

(i) *Limitations to customised uploading of visual material and relevance in the connection to online Open Repositories*: this feature needs to be expanded, with a focus on interconnecting the Metaverse to public databases and other collections available on the web. With attention to data protection and FAIR guidelines, progress can be done to extend this network, taking advantage of the native compatibility of data formats and materials. For instance, the connection with *Europeana* and its galleries, both for 2D and 3D artefacts, can be a first but decisive targeted step.

(ii) *Design and user experience feedback related to the modalities of virtual fruition and Metaverse interface*: the collection of feedback and opinions from the experience of the designed environments can allow the identification of factors for improvement in the educational perspective. For the paper’s results, questionnaires are collecting data for future analysis.

(iii) *Social interaction tools and sharing features of the Learning Environments in the perspective of future developments for the Cultural Heritage field*: the aim of making the virtual museum increasingly interactive and socially responsive is of broad interest. In particular, the collection of memories, documents, oral histories are central in the integration of digital storytelling. Through the Metaverse, such action can be conducted remotely, connecting people and contributors to cultural content even if they are physically distant. High relevance is linked to cultural communities living to present diasporas or cultural clustering.

Figure 7. Results of Spatial Environments, access with QR code

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References

Al-Tabeeb, A. K., Al-Desouqi, A. A., 2023: Metaverse in Architecture: An Approach to Documenting and Exploring the Egyptian Heritage Through Metaverse. *Green Building & Construction Economics*, 276-295. https://doi.org/10.37256/gbce.4220232300

Balletti, C., Ballarin, M., 2019: An Application of Integrated 3D Technologies for Replicas in Cultural Heritage. *ISPRS International Journal of Geo-Information*, 2019(8), 285. https://doi:10.3390/ijgi8060285

Barbuti, N., 2021: Thinking digital libraries for preservation as digital cultural heritage: by R to R4 facet of FAIR principles. *International Journal on Digital Libraries*, 22(3), 309–318. https://doi.org/10.1007/s00799-020-00291-7

Buhalis, D., Karatay, N., 2022: Mixed Reality (MR) for Generation Z in Cultural Heritage Tourism Towards Metaverse. In Stienmetz, J. L., Ferrer-Rosell, B., Massimo, D. (Eds.), *Information and Communication Technologies in Tourism* 2022. ENTER 2022 (16–27). Springer. https://doi.org/10.1007/978-3-030-94751-4_2

Burkey, B.. 2022: From Bricks to Clicks: How Digital Heritage Initiatives Create a New Ecosystem for Cultural Heritage and Collective Remembering. *The Journal of Communication Inquiry*, 46(2), 185–205. https://doi.org/10.1177/01968599211041112

Champion, E., Rahaman, H., 2019: 3D digital heritage models as sustainable scholarly resources. *Sustainability*, 11(8), 2425. https://doi.org/10.3390u11082425

Champion, E., Rahaman, H., 2020: Survey of 3D digital heritage repositories and platforms. *Virtual Archaeology Review*, 11(23), 1–15. https://doi.org/10.4995/var.2020.13226

Chong, H. T., Lim, C. K., Ahmed, M. F., Tan, K. L., Mokhtar, M. B.. 2021: Virtual reality usability and accessibility for cultural heritage practices: Challenges mapping and recommendations. *Electronics*, 10(12), 1430. https://doi.org/10.3390/electronics10121430

Cruz Franco, P. A., Rueda Márquez de la Plata, A., Gómez Bernal, E., 2022: Protocols for the graphic and constructive diffusion of digital twins of the architectural heritage that guarantee universal accessibility through AR and VR. *Applied Sciences*, 12(17), 8785, https://doi.org/10.3390/app12178785

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., Cai, W., 2021: Metaverse for social good: A university campus prototype. In *Proceedings of the 29th ACM international conference on multimedia* (153-161).

Gaafar, A. A., 2021: Metaverse in architectural heritage documentation & education. *Advances in Ecological and Environmental Research*, 6(10), 66-86.

Ghani, I., Rafi, A., & Woods, P. (2020). The effect of immersion towards place presence in virtual heritage environments. *Personal and Ubiquitous Computing*, 24(6), 861–872. https://doi.org/10.100700779-019-01352-8

Giannakoulopoulos, A., Pergantis, M., Poulimenou, S. M., Deliyannis, I., 2021: Good Practices for Web-Based Cultural Heritage Information Management for Europeana. *Information*, 12(5), 179. https://doi.org/10.3390/info12050179

Giovannini, E., 2024: Social Virtual Environments: Opportunities and Workflows in Cultural Heritage and Education in Architecture. *Proceedings of the 16th International Conference on Computer Supported Education*, 772–783. https://doi.org/10.5220/0012758500003693

Gonçalves, L., Martins, D., Oliveira, L., Amaro, A. C., 2022: Amiais in Second Life™: the use of metaverse environments to disseminate Cultural Heritage. *Observatorio (OBS*)*, 16(3). https://doi.org/10.15847/obsobs16320222215

Ibrahim, N., Ali, N. M., 2018: A conceptual framework for designing virtual heritage environment for cultural learning. *Journal on Computing and Cultural Heritage*, 11(2), 1–27. https://doi.org/10.1145/3117801

King, L., Stark, J. F., Cooke, P., 2016: Experiencing the Digital World: The Cultural Value of Digital Engagement with Heritage. *Heritage & Society*, 9(1), 76–101. https://doi.org/10.1080/2159032X.2016.1246156

Lee, C., 2023: Memorialization Through Metaverse: New Technologies for Heritage Education. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 48, 919-926. https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-919-2023

Longo, M. C., Faraci, R.. 2023: Next-generation museum: A metaverse journey into the culture. *Sinergie Italian Journal of Management*, 41(1), 147-176, https://doi.org/10.7433/s120.2023.08

Lu, S. E., Moyle, B., Reid, S., Yang, E., Liu, B., 2023: Technology and museum visitor experiences: a four stage model of evolution. *Information Technology & Tourism*, 25(2), 151-174, https://doi.org/10.1007/s40558-023-00252-1

Macrì, E., Cristofaro, C. L., 2021: The Digitalisation of Cultural Heritage for Sustainable Development: The Impact of Europeana. In Demartini, P., Marchegiani, L., Marchiori, M., Schiuma, G. (Eds.), Cultural Initiatives for Sustainable Development. *Contributions to Management Science* (373–400). Springer, https://doi.org/10.1007/978-3-030-65687-4_17

Meegan, E., Murphy, M., Keenaghan, G., Corns, A., Shaw, R., Fai, S., Scandura, S., Chenaux, A., 2021: Virtual Heritage Learning Environments. In *Proceedings Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2020* (427–437). Academic Press, https://doi.org/10.1007/978-3-030-73043-7_35

Ott, M., Pozzi, F., 2011: Towards a new era for Cultural Heritage Education: Discussing the role of ICT. *Computers in Human Behavior*, 27(4), 1365–1371. https://doi.org/10.1016/j.chb.2010.07.031

Paladini, A., Dhanda, A., Reina Ortiz, M., Weigert, A., Nofal, E., Min, A., Gyi, M., Su, S., Van Balen, K., Santana Quintero, M., 2019: Impact Of Virtual Reality Experience On Accessibility Of Cultural Heritage. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2(W11), 929–936, https://doi.org/10.5194/isprs-archives-XLII-2-W11-929-2019

Parrinello, S., De Marco, R., 2022: Experiences of Digital Survey Data Applied for the Involvement of Societal Smart-Users in Cultural Heritage Awareness. In Ugliotti, F. M., Osello, A. (Eds), *Handbook of Research on Implementing Digital Reality and Interactive Technologies to Achieve Society 5.0*. 344-386, IGI Global, https://doi.org/10.4018/978-1-6684-4854-0.ch016

SketchFab, https://sketchfab.com/feed [Last access: 26/05/2023]

Sotirova-Valkova, K., 2020: FAIR Principles for Digital Repositories: Essence and Applications for Heritage Objects. Cultural and Historical Heritage: Preservation, Presentation, *Digitalization*, 6(2), 64–76. https://doi.org/10.26615/issn.2367-8038.2020_2_006

Spatial, https://www.spatial.io/ [Last access: 26/05/2023]

Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., Wang, H., Denden, M., Bozkurt, A., Lee, L. H., Beyoglu, D., Altinay, F., Sharma, R. C., Altinay, Z., Li, Z., Liu, J., Ahmad, F., Hu, Y., Salha, S., Burgos, D., 2022: Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis. *Smart Learning Environments*, 9, 1, Springer. https://doi.org/10.1186/s40561-022-00205-x

Wang, X., Wang, J., Wu, C., Xu, S., Ma, W., 2022: Engineering Brain: Metaverse for future engineering. *AI in Civil Engineering*, 1(1), 2. https://doi.org/10.1007/s43503-022-00001-z

Xia, M., Wang, Y., Huang, J., Li, J., Fu, J., 2023: The Museum: From Digital To Metaverse. *Cambridge Explorations in Arts and Sciences*, 1(2). https://doi.org/10.61603/ceas.v1i2.17