MonA

Museopedagogy and Augmented Reality

Summary for Museum Professionals

2019-1-EL01-KA201-062965

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SUMMARY FOR MUSEUM PROFESSIONALS

Museopedagogy and Augmented reality: Recognizing museums as educational spaces
2019-1-EL01-KA201-062965.

https://www.monaproject.eu

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Glossary

This Glossary provides explanations on some of the key terms used in this document

- By **museopedagogy** we mean the set of methodologies and tools used by museums and schools to make collections, exhibitions and in general, any kind of cultural exhibition accessible to a wider public, even young people.

- **Lifelong learning** is all learning activity undertaken through life, with the aim of improving knowledge, skills and competences within a personal, civic, social and/ or employment-related perspective (European Commission [EC], 2001, p. 9).

- **Museum** Is a permanent, non-profit institution, open to the public, at the service of society and its development, which researches, acquires, conserves and, above all, exhibits the testimonies of humanity and its environment for study, education and enjoyment (see ICOM Statute, 1951).

- **Gamification** is the strategic attempt to enhance systems, services, organizations, and activities in order to create similar experiences to those experienced when playing games in order to motivate and engage users (Hamari, 2019).

- **Museum Heritage** is the economic and symbolic value of the museum sites added to the items exhibited or stored, to the services

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offered and to the employment resources determined, and to the capacity for cultural enterprise development, both at the local level and at a broader level.

- **Active Learning** is "a method of learning in which students are actively or experientially involved in the learning process and where there are different levels of active learning, depending on student involvement. (Bonwell & Eison, 1991).

- **International Council of Museums** (ICOM) is the leading international organization representing museums and their professionals. The organization assists the museum community in preserving, conserving and sharing its present and future cultural heritage, both tangible and intangible. It was officially born in Paris in 1946, on the occasion of the first general conference of UNESCO.

- **Augmented Reality** (AR) is the result of real-life objects with digital information attached to them. AR refers to all situations in which the display of an otherwise real environment is altered, or augmented, via the use of virtual computer graphics (Milgram and Kishino, 1994).

- **Virtual Reality** (VR) is an artificial three-dimensional environment in which the objects have a sense of special presence. They way that this environment is presented to the user is such that the user suspends belief and accepts it as a real environment.

- In **Mixed Reality** (MR), users are placed in a real world environment where real and virtual content coexist and interact in real time. In other words, the virtual content is totally integrated into

the real world surroundings via MR headsets and the user can interact with both real and virtual contents at the same time (Bekele et al., 2018).

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Abbreviations

AR: Augmented Reality

VR: Virtual Reality

MR: Mixed Reality

ICOM: International Council of Museums

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1. The MonA project

Project "**MonA: Museopedagogy and Augmented Reality**" is an Erasmus+ funded program in the period between October 2019 and December 2021. The project seeks the convergence of culture and education through the creation of an integrated educational program for the younger audience and especially the school audience provided in small museums, mainly in the province of EU countries, using modern technology with emphasis on augmented and mixed reality.

This project is a collaboration between ten (10) partners from four (4) different European countries: Greece, Italy, Austria and the Netherlands. The partners are divided in three categories: school partners, museum partners and technological partners. Each partner category played a different role in the implementation of this project: while schools were responsible for enhancing the pedagogical character of the outputs produced, museums were the end users of the outputs of this project and technological partners took advantage of their great experience on the management of European projects, together with experience in ICT tools development.

The Coordinator of the project, **the Research Center of Music – Museum of Vasilis Tsitsanis** is located in Trikala city, Thessaly, Greece and its purpose is to research, collect, conserve and exhibit the music of Vasilis Tsitsanis, the famous Greek Rebetiko composer

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and lyricist. Along with Palazzo Lucarini Contemporary, based in Trevi, Italy, Karikaturmuseum Krems, based in Krems an der Donau, Austria and Nemo Science Museum, based in Amsterdam, the Netherlands, constitute the museum partners of the project.

The school partners of this project are the Music School of Trikala, Greece and the Liceo Classico “Federico Frezzi - Beata Angela”, based in Foligno, Italy. The technological partners of the project are the following: Developmental Center of Thessaly (AKETH), based in Trikala, Greece, Amsterdam University of Applied Sciences, based in Amsterdam, the Netherlands, European Grants International Academy Srl, based in Foligno, Italy and IMC University of Applied Sciences Krems, based in Krems an der Donau, Austria.

The project has the following goals:

- Shape the perception of small and medium-sized museums as places of learning
- Highlight the potential of technology as a means of promoting and learning about Europe’s culture
- Highlight the potential of technology as a means of attracting children and young people to the cultural wealth of Europe
- Promote the educational programs provided by museums as additional to the education taking place in the classroom
- Develop co-operation between museums and school communities to provide modern education

The **target audience** is the school community of EU countries with a direct focus on pupils and teachers in the partner areas as well as

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all the organizations, institutions and persons involved in educational activities within museums.

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2. Goal of the Summary

The goal of the "**Summary for Museum Professionals**" is different than the Guide to museopedagogy with the use of modern technology. The target group of the Summary consists of museum professionals, museopedagogists, museum educators and any other museum staff that is eager to create digital educational material for its audience, whether this is young people or adults.

The Summary is a practical tool - a shorter version of the Guide - that can be easily used when creating educational programs. In this document the consortium has managed to summarize the technological aspects of the use of new technology for the purposes of museums in an effort to disseminate this content with a greater ease, reach out to a wider audience and have a greater impact on museum professionals.

The digital era, that has been accelerated by the pandemic of Covid-19, has shaped the "business as usual" inside – and outside – of museums. Technology is advancing and museums has been already taking the opportunity to adjust ICT tools in the material that they produce for visitors. In recent years we have seen more and more museums going digital, or embedding technology in the museum experience with multiple other ways.

Through this Summary, the aforementioned target audience will be able to have a concrete view on the basics of Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR). This is the

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technology that was used for the Intellectual Outputs of MonA Project, the technology that makes museum professionals free to reimagine their museum and transform the way their organization operates. Today, none can ignore the great potential that this kind of technology has for cultural spaces and a holistic view to the issue can help them excel in modern age.

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3. Museopedagogy and Existing methods

Before moving to museopedagogy it's important to define the museum space. According to the definition of the ICOM, the international organization of museums and museum operators, the "museum" is "a permanent, non-profit institution, open to the public, at the service of society and its development, which researches, acquires, conserves and, above all, exhibits the testimonies of humanity and its environment for study, education and enjoyment (see ICOM Statute, 1951).

By "museopedagogy" we mean the set of methodologies and tools used by museum and schools to make collections, exhibitions and, in general, any kind of cultural exhibition accessible to a wider public, even young people.

It seems particularly useful and interesting to retrace the main phases of the establishment of Museopedagogy in Europe after the Second World War when we start talking about "museopedagogy". In the general framework of the recovery of civil life, after the hard period of war, international organizations such as UNESCO (1945) and ICOM (1946) were born, many museums reopened to the public with innovative cultural programs, whose common denominator was a great cultural and civil commitment. Museums today are unique

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cultural institutions, as they are easily accessible and present unique exhibits for study and entertainment too.

Both school and the museum are two different institutions united by a single ideal objective: the recovery and study of the past for the development of the future.

As we are living in an era of great social, cultural and economic transformation, schools have the task of training new citizens, passing on the knowledge and culture of the past to the new generations; preparing young people for the society in which they will live so that they are able to understand it and contribute to its change.

Making schoolchildren visit museums and exhibitions is considered a fundamental educational tool, because through museopedagogy awareness of the cultural heritage, disciplinary knowledge, cognitive and historical skills, visual, aesthetic and scientific thought is developed, as well as the development of a regular relationship and confidence with the artistic heritage and the spaces that host it permanently or temporarily, as schoolchildren are the adult visitors of the future.

The methods that are implemented in museopedagogy, use to focus, depending on their unique characteristics, in education, entertainment, engagement, experience, personal expression and creativeness. According to Dreykorn and Wagner, museopedagogy has adopt a variety of different methods that include music, dance, research, writing and more, while at the same time, as we have to do with museums and original and unique exhibits, it is considered

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highly important to activate all the senses: vision, touch, smell and hearing.

A method can be considered successful, when it holds the visitor's attention for the exhibits and makes them to express personal thoughts and seek for answers (Dreykorn & Wagner 2007a: 160).

3.1 Narrative methods are taking place in museums through different forms and are applied in multiple activities. A primary element of these methods is the receptive stance of the visitors, as they lack any capacity of personal expression and interruption on the narration's storyline. Historically, the most famous educational activity of museum practice is the Guided Tour.

3.2 Directed Discussion is the most characteristic method of Museum Pedagogy. It is mainly applied to two different activities: "educational tours" and "discussions", which can work either as autonomous activities either as a part of a broader educational program. The peculiarity of the Directed Discussion is the introduction of elements of dialogue in the traditional tour/ narration in order to highlight the communication dimension of the exhibits and museums in general, and their active approach by the visitors (Thinesse-Demel 1994, Ulbricht 1994).

3.3 Through **Exploration based methods**, learning through discovery presupposes an active learning process, in which visitors discover and connect with the stimuli of the space and so they can experiment, handle, explore by gaining this experience. Visitors can really discover something (Hein 1998: 38).

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3.4 Experiential-creative methods are a key tool of the museum pedagogical practice, moving in two educational parameters crucial for the modern museum, a. of experience and b. of creative expression. The concept of experience is linked to the role of museums as spaces non-formal education with importance for leisure that recognizes learning and entertainment as complementary elements (Bäumler 2003, Commandeur & Dennert 2004).

In our days, museums are focusing to embrace and further support the communication between the visitor and the museum which overall benefits both sides and offers to visitors a unique experience. They have the potential and the means to offer to the visitors an experience where they will be able to interact with the socio-cultural environment in a new undiscovered way. Museopedagogy is the one to demonstrate the aforementioned communication and its complexity to visitors' minds and feelings.

4. AR in museum education

Apart from traditional museum booklets, guided tours and audio guides, new technology is used to enhance visitor experience and education. A big focus of current museum education projects lies on Augmented Reality (AR).

According to the English dictionary, “to augment” means to make something greater by adding something else to it. If we apply this definition to reality (the real world around us), augmented reality (AR) is the result of real-life objects with digital information attached to them. AR refers to all situations in which the display of an otherwise real environment is altered, or augmented, via the use of virtual computer graphics (Milgram and Kishino, 1994).

Unlike in Virtual Reality, when using AR, the user can see the real world around him/her. This view has graphic overlays, like text, pictures, 3D models, and videos on it. AR merges the real world with virtual objects, which can be enhanced through sounds, and interactions (Mancebo May, Schmidt and Vlachopoulos, 2020).

The earliest functional AR systems that provided immersive mixed reality experiences for users were invented in the early 1990s, starting with the Virtual Fixtures system developed at the U.S. Air Force's Armstrong Laboratory (Rosenberg, 1993). Since then, the

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adoption of AR applications is rapidly increasing – which is mainly due to the availability of hardware and software components enabling the use of this technology and the awareness about the benefits of these technologies. These days many industries such as education, communications, medicine, and entertainment are using AR to enhance natural environments to offer enriched experiences to the users (Mancebo May, Schmidt and Vlachopoulos, 2020).

No matter whether it is an App by IKEA, where customers can use the app to see how tables and shelves would look in various places around their house or the app by the beauty company L'Oréal that allows users to try out various types of makeup – AR is already being successfully used in various business contexts. Customers can try/use products in a virtual environment and see the results in the context of the real world (e.g., Gucci – 'try on' shoes in AR). Similarly, several examples can be found in tourism (e.g., city navigation with virtual labels on real buildings), repair and maintenance of complex equipment (e.g., repair instructions for gas turbines), advertisement (e.g., selling trips, travel, and vacations). These applications have a significant potential to improve the perceived value of traditional activities and add benefits for customers and businesses.

The adoption of AR in museums is gaining momentum as there are more and more examples of successful applications (Yoon and Wang, 2014). Svevo Museum in Trieste explored the relationship between AR technology and storytelling techniques to indulge adult visitors without previous experience of AR to improve the overall visitors experience (Fenu and Pittarello, 2018). Hong Kong Space

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Museum used augmented space to replace interpretive guides to build up a strong link between the exhibit, environment, and visitors (Jin, Wang and Hikes, 2017). Other examples are encouraging the use of AR, as shown by Tom Dieck and Jung (2017) using a case study from a small museum in the UK to explore the perceived value of the implementation of AR within the museum context. The Smithsonian National Museum of Natural History in Washington, DC has a special way to 'see' skeletons on display in the Bone Hall or printed on paper and on a monitor. It brings skeletons to life and creates the same 3-D experience at home or in the classroom. In the Archaeological Park Carnuntum, Austria visitors can view virtual images of now invisible buildings from the former roman capital of Carnuntum. The content is delivered through different visualizations techniques and allows the user to change the scenes.

Figure 1 *Augmented View of Roman City of Carnuntum*

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Imagine every object in a museum being a potential projection area to display additional information about the objects without needing traditional booklets or labels and texts on the wall. Extra digital information could be provided for any object, even in different wording and languages to cater the needs of the visitors, like children and adults. This helps to make background information easier to understand without needing further exhibition space or print material. Through using modern technologies, the museum exhibitions become more engaging for visitors.

As most students are already familiar with IT gadgets like smart phones and tablets, this scenario of using such existing devices to transform museums into a new type of learning environment is not far-fetched. The potential of combining smartphones and AR for education is great. Research shows that learning experiences with AR and the interactivity that comes with these applications have a positive impact on the students (Pérez-Sanagustin et. al., 2014). This results in higher student engagement and interest, which makes learning fun and effortless. In general AR can be used to enrich content, increase engagement of the students, provide interactive experience and to gamify learning environments (Stoddard et al. 2015).

Enrich content – AR is a good choice of technology, when students need to understand the meaning, context, and significance of different elements in the object. This can be achieved by blending information such as textual descriptions, dates, numbers, photos, videos etc. to the objects of concern.

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Increase engagement – Through AR, lifeless artifacts in a museum can come back to life. Animations and other visual effects can be used to give students a better sensation of the size and perspective of the otherwise static artifacts.

Provide interactivity – Interactive experience gained through zooming, rotating, or moving virtual objects enhances active and reflective learning (Chang et. al., 2014). The possibility to watch the virtual objects is already appealing for most students, however the possibility to play with these objects, change their shapes, sizes, forms, or locations fascinates even more. This engagement can effectively enhance students' learning effectiveness, promote their flow experience, and extend the amount of time they spend on learning activities in the Museum.

The benefits of the use of AR technology in museums are numerous. The process of creating such an AR app has improved over the last years and is easier than before. A big part of the development, such as defining the storyline for the app, can be done by museum professionals themselves. As AR applications must first detect the environment and then determine what should be presented on the virtual layer, the first step in the process is to define the environment where the app should be used. The next step is to decide what kinds of real-world objects should activate the AR function. This is typically done by defining markers which are visual cues that trigger the display of the virtual information. After content and markers are defined and developed, the implementation of the app can be finalized in short time by IT professionals.

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The trend in the adoption of AR technology shows that the full potential of this technology is yet to be exploited. This is driving innovation in this area and the technology itself is constantly improving. This has led to convincing and realistic interaction of the virtual and physical environment, and improved user experience.

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5. VR in museum education

5.1 What is VR?

Virtual reality or VR is an artificial three-dimensional environment in which the objects have a sense of spatial presence. The way that this environment is presented to the user is such that the user suspends belief and accepts it as a real environment. Considered as an interactive, immersive, multisensory experience that is understood primarily through two of the five senses: sight and sound.

An environment for Virtual reality is created with software and the experience relies on threedimensional, stereoscopic, head-tracked displays, hand/body tracking, and binaural sound. In literature and on the Internet, VR is also referred to as virtual environments, virtual worlds, or microworlds.

The idea of immersion is that the user is surrounded with images from a digital 360° environment. It is a deep mental and visual involvement from the user. For example, the user of VR can be immersed in the ocean and explore the seabed or find himself flying among the stars. Immersion is enabled thanks to VR headsets and to virtual 360° videos.

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Interaction is essential for a user to be involved and engaged in the VR experience. The user is no longer a viewer but a performer. His/her decisions have an impact on the scenario, and he/she can decide, seize, manipulate or influence the experience. To enable interaction, captors, sensors and controllers are essential. However, while many videos or programs claim to be using VR, they don't offer the possibility for the user to have any interaction.

In the Past

In the past three decades, virtual reality has predominantly been a tool of the gaming industry, and development of user experiences for enabled hardware have largely been related to entertainment. One of the very first "VR" experiences is considered to be held in 1968 and is called "the sword of Damocles". In order to wear the head mounted display, the scientist had to be under the computer that was suspended from the ceiling. At that time all he could see was really simple and primitive images such as wireframe cubes.

5.2 Equipment

Now there are a lot of possibilities for one to experience VR. The most important element in order for someone to experience VR is a headset. There is a big variety available in the market, but there are three main categories of VR headsets that enable different degrees of freedom to the user:

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- Mobile Virtual reality headset (eg. Google CardBoard, Google Daydream View or Samsung Gear VR)
- Desktop headset VR [Oculus Rift S, HTC Vive, PlayStation VR (PSVR)]
- All in one VR headset [Oculus Go]

5.3 VR in (museum) education

Introducing VR in Education

Virtual reality has the potential to greatly enhance the learning experience and active engagement in many ways. Research shows that both virtual and augmented reality simulations increase student motivation and improve collaboration and knowledge construction.

Even though the area of study is yet to be explored, Virtual Reality has proven to enable:

- A better sense of place, as the student can learn about a subject by living it.
- Scale learning experiences, eg.: A VR device can act as a whole science lab.
- Learn by doing.

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- Emotional reaction, VR makes it easy to engage students, making experiences memorable.
- Develop creativity.
- Visual learning, as described above the leading senses used in VR are vision and hearing
- Familiarity with high-end modern technology.

Are the principles of physical museum applied to its Virtual Form?

Collect:

The physical objects of a museum are totally different from the exhibits that are displayed in a virtual exhibition. Thus, the collection of those cannot take the same form. But who said that collection is only applied to physical objects?

One way for a virtual museum to collect data would be through web logs (Deshpande, Suhas 2007). With the help of web logs the virtual museum could track data based on the audience of the virtual museum. Not only would this provide a lot of information about how the audiences approach the virtual museum in question (Henning, Michelle, 2006), but also about Internet usage in general.

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Preserve:

When we talk about a born digital collection, such as 3D environments, net art and digital art, then the formation of preservation is distinctive. The problem with born digital material is not necessarily storage, but mainly that of digital heritage longevity. New file formats and standards are constantly introduced, and old ones are discontinued (Addison, Alonzo, C., 2007), making it a necessity for the collection to be revised.

Display:

The virtual world does not have the same limitations as the physical museums when it comes to putting together combined exhibitions with artifacts from several museums. The cost, time and care that museums have to spend today on every single artifact they borrow from another museum make it difficult for most museums to go through this process (Walczak, Krzysztof 2006).

Type of exhibitions of the Virtual Museum

- **In-depth object exhibition**

This kind of exhibition centres around the object, which can seem difficult in the case of the virtual exhibition, however, in-depth object exhibitions present the object in a different manner compared to how it is presented in a physical exhibition.

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In many ways, virtual in-depth object exhibitions actually present objects in a more thorough way than what would be possible in a physical exhibition and could pose an invaluable source for research, locally as well as globally. They succeed this, through the use of 3D photography and VR tools.

- **Thematic exhibitions**

The core of the thematic exhibitions in as well physical as virtual shape, is the theme rather than the object. Since the virtual exhibitions were first introduced, there have been concerns regarding virtual exhibitions and their lack of object-centered authenticity.

- **Interactive exhibitions**

Interactive exhibitions are virtual exhibitions where the museum or cultural heritage institution provides a framework for a virtual exhibition, but where the user and audience contribute material to the virtual exhibition.

5.4 Examples of good practices

Today, thousands of museums around the world have developed multiple virtual tours or have even transported all their exhibitions in their web page, thus acquiring as museums a second existence – the virtual one.

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MonaLisa

One of the most renowned exhibits, Mona Lisa, went virtual in 2020. Mona Lisa: Beyond the Glass was the first virtual reality experience presented by Musee du Louvre. Mona Lisa is kept permanently in protective casing due to its fragility, making visitors miss most of its great beauty.

Figure 2 *Mona Lisa can now move through virtual reality, providing us with more information, making visitors miss most of its great beauty.*

Mona Lisa: Beyond the glass, offer visitors the chance to go inside the painting. They can get closer to the painting, discover its story and the method that was used by its painter. X-ray was used in order to determine how she was dressed and how to portray her face in the hologram that was created.

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The British Museum

Through virtual reality, visitors from around the world can now admire this masterpiece and get a personal encounter with this artwork. They can now see the vivid details of this celebrated oil painting, including the texture of the wood panel seen through the paint layer, and the marks where the panel once cracked and was masterfully restored.

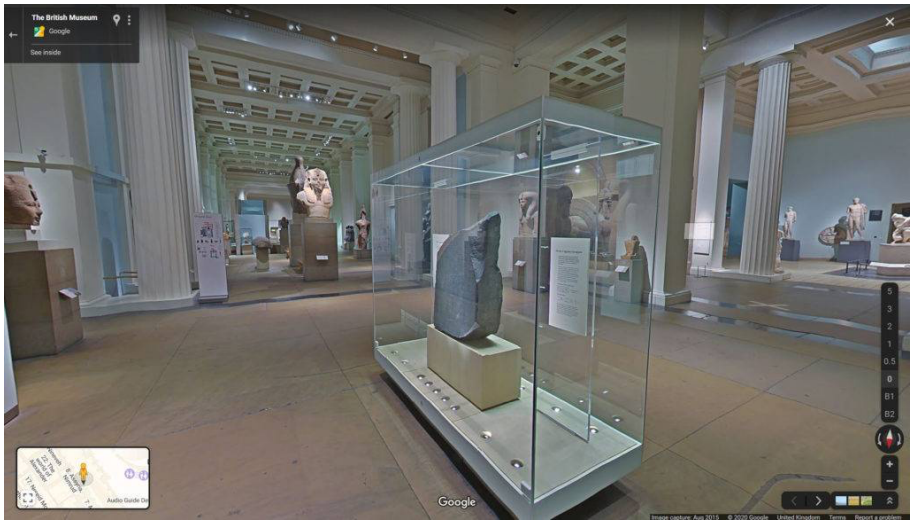

Figure 3 *British Museum, the world's largest indoor space on Google Street View.*

With a collection that totals more than 8 million objects, London's British Museum made some of its pieces viewable online. The museum also teamed up with the Google Cultural Institute to offer virtual tours using Google Street View technology.

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6. MR in museum education

6.1 What is MR?

In Mixed Reality (MR), users are placed in a real world environment where real and virtual content coexist and interact in real time. When you use VR, you are completely immersed in a virtual environment via VR headsets. You do not see the real world around you. In AR, you can see the real world around you through smartphones, tablets, heads-up displays, or AR glasses. You see the real world around you with virtual overlays, such as text, pictures, sounds, 3D models and videos.

The main environment of both AR and MR is the real world and users can interact in it with the virtual content, the key characteristic of Mixed Reality(MR) is that the virtual as well as the real content are able to react to each other in real time (Flavián, Ibáñez-Sánchez and Orús, 2019).

A good example to illustrate this, is the interactive Hololens application Dynamic Anatomy. This is a project by Leiden University and the Leiden University Medical Center (LUMC) in the Netherlands. In this application, students can not only see a virtual 3D anatomical model of the ankle joint, but because this model is connected to the human body movements by motion tracking, the

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medical students can learn from their own real-life physical movements while studying the virtual 3D model (Hierck, van Melle and Hurkxkens, 2017).

Figure 4 *Learning with the Hololens app DynamicAnatomy. (source: https://www.microsoft.com/en-us/p/dynamicanatomy/9nwlj4qg053p?activetab=pivot:overviewtab)*

6.2 Equipment

Popular MR systems are the Magic Leap (a wearable spatial computer that brings digital and physical worlds together), Meta 2 Headset (headset with holographic projection), and the MicrosoftHoloLens (Okaro & Vlachopoulos, 2020). These immersive systems allow museum visitors to engage with an exhibit interactively, navigating its surroundings and visiting various spots of interest.

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Compared to AR and VR the technology used for MR is not easily accessible. Where, for VR there are cheap options, like Google Cardboard, available and for AR you can often use your own device and ready made content, for MR you need special gear. Museums can use this as an opportunity; the technology is still new and special so it can be used as a standalone exhibit to showcase the technology. But it also brings up a big obstacle: money.

6.3 MR in Museum Education

Education and MR

In chapter 5 the insights on AR and education are described in detail. The benefits described there; enrich content, increase engagement, provide interactivity and gamify learning environments apply in almost the same way for MR. Therefore, in this chapter we will zoom in on the possibilities that apply especially for MR. To recall; the difference between AR, VR and MR is that in MR the user can interact with the virtual layers and each other at the same time. As shown in the picture below.

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Figure 5 *People interacting and seeing mixed reality at the same time. (Source: Courtesy of Interactive Commons of CWRU)*

Compared to VR and AR, MR provides a more immersive experience because you can virtually touch and manipulate objects. (With a motion controller, or by walking through or 'tapping' the space.) This immediately brings up a benefit compared to the other technologies: you can let the students/visitors work together and they can still see and safely navigate the surroundings while using the device. For example; students can walk around and interact with a 3D hologram of a body while also seeing instructors and classmates.

As you can imagine this way of learning has a bigger learning outcome than learning from a book. This also applies to VR and AR; a comparative study between a full-body mixed reality simulation and a desktop version of the same simulation, showed that students had a better experience learning about scientific topics such as

gravity and space movements in a mixed reality environment (Lindgren, 2016).

Museums and MR

MR can be used in different ways in museum education:

- Enhance audio tour experience with visuals.
- Replace audio or guided tours with holograms.
- Use a hologram to put a virtual teacher in the space, or an educator or even historical characters.
- Enhance existing exhibits or artifacts with AR by showing scale or layering—for example, showing a full dinosaur over its skeleton.
- Use MR technology as a standalone exhibit (for example in a game).
- Provide access to exhibits that you normally can't look close to or manipulate.

6.4 Examples of good practices

The Plan Relief museum in Paris uses MR to create a digital layer over a model of le Mont Saint Michel. With the Hololens, you can walk around the model and see digital layers projected on it. There is also extra information and videos beside the model. The difference with AR, is that you can experience the digital layer at the same time as other people.

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Figure 6 *Three people experience the same digital model. (Source: Still from: Microsoft youtube)*

MR can also be used as a digital guide. The Intrepid Sea, Air & Space Museum in New York City uses a hologram as a digital guide. The hologram of Mae Jemison (the first woman of color in space) explains the visitor about the role of woman in space exploration. The visitors walk around a spacecraft while Jemison narrates. The tour also includes a life-size rendering of an astronaut doing a spacewalk and a look inside the spacecraft. This is an example of a very immersive and interactive experience for the visitor.

Figure 7 *Astronaut Mae Jemison appears as a 3D rendering (above, left) (Source: www.smithsonianmag.com/smithsonian-institution/hologram-first-woman-color-space-debuted-museum-day-180970417/ photo by: Brandon Kaiser)*

Museum de la liberation takes this a bit further. They use the HoloLens to let visitors explore the underground headquarters of the French Resistance during Insurrection Week. The visitor walks through the bunker with the Hololens. And the Hololens shows the reality of what's in front of you with an added layer of visuals. The visitor takes on the role of a journalist. Through the Hololens different digital characters approach the visitor and speak to them directly. Furthermore the visitor can see animation of how the space used to look during the resistance and interact with the (digital) objects, testimonies, and recordings.

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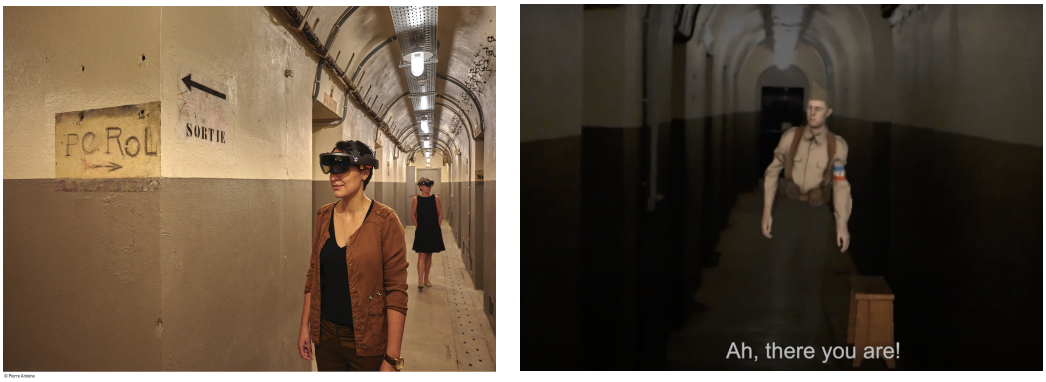

Figure 8 *Mixed Reality Experience in Musée de la Libération de Paris (Source: https://www.microsoft.com/inculture/arts/museum-liberation-of-paris-mixed-reality/)*

Another example of using MR to totally immerse the visitor in the experience can be found at COSA in Graz. They created a game using MR technology; the CoSA_A(R)dventure. This museum uses the Hololens in combination with physical exhibits to create a game about climate change. A difference with the Museum de la liberation is that the visitors can experience the game together. They are helped on their quest by a little flying robot that functions as a guide in the three rooms with different adventures.

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