Remote Visiting, Close Experiencing:

Visiting Virtual Museums Through The Lens Of Virtual Reality

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Media Arts and Technologies

PSY594: Learning and Instruction with Media

June 6th, 2022

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With the vast development of the Internet and Virtual Reality technology, gradually, a growing number of museums have opened their digital access to the public through immersive virtual museums. How can visiting immersive virtual museums help promote visitors' learning outcomes? Is there any research evidence to support this trend? How can we design these immersive virtual museums to promote learning better? This work aims at giving a brief literature review of the recent research related to learning outcomes of immersive virtual museums and would like to address the questions mentioned above. Part two of this work gives a brief proposal of a future work inspired by this literature review.

What is an immersive virtual museum?

Since the nineteenth century, museums have been regarded as social environments where the general public, schools, tourists, and scholars might visit and learn (Pierroux et al., 2022). Previously, visitors have had to visit museums to get information physically; however, with the development of the Internet and displaying equipment, now it is increasingly possible for the providers to reach out to different museums from their homes, workplaces, and schools virtually, through online platform(Bowen, 2000). The lockdown of COVID-19 since 2020 pushed the situation even further. More than 90% of museums worldwide were shut down during the period (UNESCO 2020). As a response, more museums have started to provide digital access to the public, including social media, streaming content, virtual tours, online webpage exhibitions, and games (Zuanni, 2020). Among them, virtual tours occupy a large portion.

The online virtual tours vary significantly in their look and feel. The simplest form of a virtual tour is a type of 2D multimedia application or static web page containing text, photographs, videos, and audio. More advanced applications are usually constructed with high-quality photorealistic 3D reconstructions of the museums. Visitors are provided with a Desktop interface to navigate through these virtual environments. With the development of Virtual Reality and web technologies, users can also use Virtual Reality equipment to visit these virtual museums in a high immersive way in some applications (Fokides, 2008). With these virtual environments, visitors are provided with unique opportunities to look at all the artifacts, move around the environment, interact with exhibits with no lines of waiting, create their exhibits and connect with other users, which would be hard to achieve in a real museum (Jones & Alba, 2019). Some proponents also suggest these immersive virtual museums will construct effective engagement with the exhibitions, arouse motivations, and promote students' constructivist learning.

As illustrated in Chapter 42 of the textbook (Mayer & Fiorella, 2022), immersive media can function as an effective instructional method to improve learning. Museums, like informal learning environments, are promising to foster this feature. This work attempts to address the following questions:

1. What does visiting an immersive virtual museum mean to users based on cognitive theory?
2. What does the research evidence say about the effectiveness of immersive virtual museums on visitors' learning outcomes?

3. How can we design these immersive virtual museums to promote learning better?

Examples of visiting immersive virtual museums

Examples of immersive virtual museums can be very easily found online. But as mentioned ahead, the usage, forms, and developing methods vary greatly.

With Quicktime Virtual Reality or With 3D modelings

Based on how the virtual museums are developed, they can be categorized into two types: With Quicktime Virtual Reality (QTVR) or With 3D modeling. For the QTVR type, virtual museums are created by taking overlapping still pictures of the museums from a tripod with a panning head. Virtual museums are basically real-world still pictures that are processed and distorted to form a 3D illusion. These types of virtual museums provide a more realistic reconstruction of the real-world museums and require much less developing effort. At the same time, the interactive methods that visitors can adopt are generally limited to navigating through different positions, changing viewing angles, zooming in, and clicking the exhibitions for further explanation. This method is commonly used in the construction of virtual museums, such as the Smithsonian National Museum of Natural History (http://naturalhistory.si.edu/vt3/), Rijksmuseum(https://artsandculture.google.com/partner/rijksmuseum), and The Palace Museum (https://en.dpm.org.cn/multimedia/virutual/) Other museums choose a more complicated method to create a virtual world that highly resembles those in the real world using 3D modeling and editing software such as 3D Studio Max, Unity, Unreal Engine and Blender. These virtual

museums are constructed with 3D models built by scanning the original objects or by developers in entirely virtual environments, thus requiring much more development effort, but can provide users with more interaction opportunities and have a plentily different museum experience. For example, in the Louvre's stunning Mona Lisa: Beyond the Glass (https://www.viveport.com/18d91af1-9fa5-4ec2-959b-4f8161064796), users' can walk in Mona Lisa and interact with the 3D living Mona Lisa at home with VIVE VR. Smithsonian American Art Museum also has its virtual museum tour application on Steam called "Beyond The Walls" (https://store.steampowered.com/app/1087320/Smithsonian_American_Art_Museum_Beyond_The_Walls/) also created that is fully based on 3D scanning and modeling.

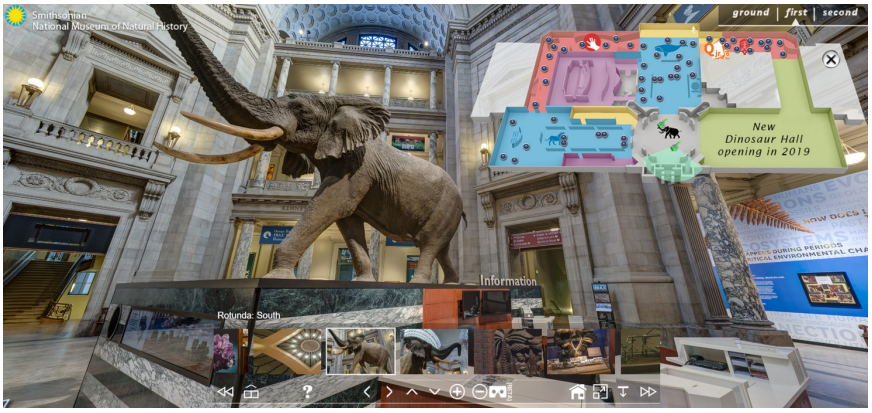

Fig1: A screenshot of the Smithsonian National Museum of Natural History's virtual museum

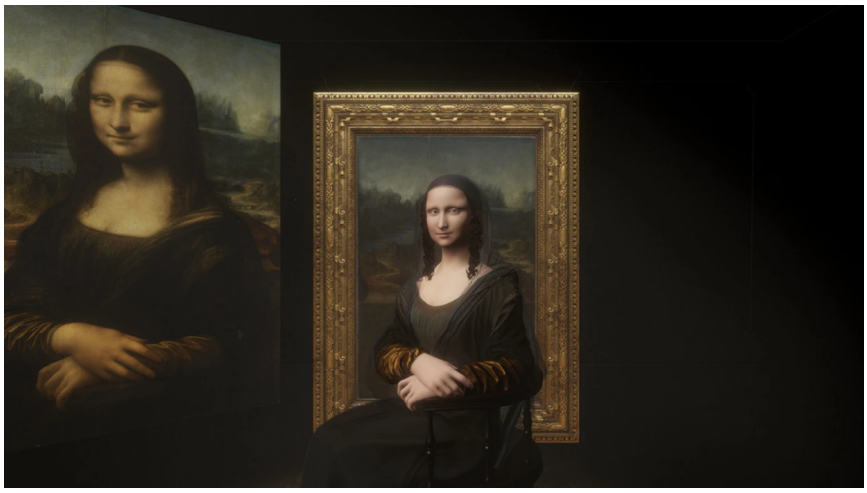

Fig2: A screenshot of the VR application of Louvre's Mona Lisa: Beyond the Glass

Low-immersive Virtual Reality or High-immersive Virtual Reality

Based on how virtual museums can be visited, similar to Chapter 42, immersive virtual museums can be cataloged into two types: low-immersive virtual reality (desktop-displayed VR) or high-immersive virtual reality (head-mounted displayed VR). Most of the applications designed based on QTVR are web-based and support both desktop VRs and HMD VRs. However, some 3D modeling-based virtual museums need to run with Steam or Oculus and can only run with powerful hardware and HMD VR equipment, such as "Beyond The Walls" and Mona Lisa: Beyond the Glass.

Organized by Museums or by Third-party platforms

Based on how the virtual museums are organized, they can be categorized into two types: By museums themselves or by Third-party platforms. Many museums have implemented virtual

museum access on their webpage. Another type is that virtual museums are constructed and operated by third-party platforms. These platforms usually contain various access to different museums so that users can visit different museums from one webpage. Google Art & Technology has partnered with over 500 global art institutions to open their virtual doors to the public.

A Literature Review of Immersive Virtual Museum

According to what I've learned so far, there is little attempt to review research on the influence of immersive virtual museums on learning outcomes. However, this growth of immersive virtual museums has led to an accompanying rise in research targeting its usability, effectiveness, and viability (Jones & Alba, 2019). Based on my collected information, I adopted and modified the three genres of game research summarized in Chapter 40 (Mayer 2019), then applied them to this research topic. I categorized the experimental studies in this area into the following genres.

- Value-added Research: Similar to what Mayer has defined, the goal of this type of research is to find which features in immersive virtual museums can promote learning.
- Method Comparison Research: Different from the "Media comparison research", this type of research is to determine whether people learn better from immersive virtual museums than from real-world museums.

- Media Comparison Research: this type of research is to determine whether people learn better from immersive virtual museums than from conventional media such as 2D images and text.

17 papers were selected in this literature review from the online search results. The strategy is to keep works that: 1) evaluate functions of 3D virtual museums instead of 2D, and 2) contain empirical studies to evaluate the learning outcomes and cognitive perceptions.

Media Comparison Research

This type of research focuses on determining whether users can learn better from immersive virtual museums than from traditional virtual museums based on websites and 2D images and text. This research topic is crucial because it talks about whether the benefits of immersive virtual museums can overweight the cost of evolving from 2D to 3D, just as the discussion in Chapter 42. Five of the seventeen studies talked about this topic. In most of the research, 3D immersive virtual museums have been proven to promote learning outcomes better than traditional methods.

The study of Zouboula et al. (2008) aimed at proving that the construction of VR applications is within the abilities of the majority of computer users and is an effective and low-cost instructional tool for everyday teaching. They compared primary school students learning from PowerPoint Slides (G1) and from desktop immersive virtual museums (G2) through a controlled study and concluded that students from G2 had better learning results and showed a continuous interest in the class topic.

The study of Katz & Halpern (2015) also proved that participants who experience 3D virtual museums present a higher sense of interacting with exhibitions, a more positive attitude, and stronger intentions to visit the museum than participants in the 2D condition. Moreover, they also found that the more realistic the virtual museum looks, the more substantial effect engaging learners' learning process will have.

Ambusaidi & Al-Rabaani (2019) compared the learning outcomes of students taught by virtual museums and students taught by traditional methods of slides. Significant differences were found between the groups in the achievement tests and their attitude toward archaeology, favoring the assumption that learning with immersive virtual museums helps promote learning.

Research results show conflicting conclusions. In Kostoska et al. (2015), the researchers compared the learning outcomes of older adult participants who visit immersive virtual museums with participants who obtain 2D information. Results showed that although the immersive virtual museum is more aesthetically appealing to the old than the traditional ones, this method does not lead to higher performance because almost no participant could actually use it. The participants reported that they felt disoriented and were not able to navigate. This result shows that the boundary conditions of immersive virtual museums would be age and 3D navigation ability.

Earlier work also showed that 3D is not always better than 2D. Hendricks et al. (2003) compared participants learning behaviors in 2D and 3D galleries and concluded that the 2D gallery was found to be more suitable for educational purposes as visitors spent 30% more time reading information on the artwork in the 2D gallery than the 3D gallery. It shows the negative

effect of the immersive principle mentioned in Chapter 24 that the immersive experience might distract the learning experience.

Studies on this topic show a mixed result but slightly in favor that learning from immersive virtual museums promotes learning outcomes than learning with traditional media. However, all the studies are conducted with low immersive virtual museums instead of high immersive ones. And the museums' topics are all about arts & history instead of science & technology.

Method Comparison Research

Research on this topic compares the experience of visiting immersive virtual museums with the experience of visiting real-world museums. We learned from Chapter 42 that the two critical theories of immersive instructional tools are immersion and presence, which talk about making users feel the environment is real. It is hard to require immersive virtual museums to promote learning outcomes than real-world museums more effectively. Although Virtual Reality can offer museums completely new ways to connect with audiences, nowadays, most of the available immersive virtual museums still focus on creating realistic virtual exhibitions like real-world exhibitions. Therefore, most of the research on this topic evaluates not only the learning outcomes of participants but also their cognitive experiences, such as their enjoyment and engagement. Seven of the seventeen studies in this literature review are mentioned.

Marín-Morales et al. (2019) did unique research to analyze the psychophysiological patterns in a free exploration of an art museum in immersive virtual museums and in real

museums. They constructed a virtual museum in Unity about a very emotional topic, the Nazi Holocaust, and conducted a controlled study with 60 participants. Results show that the virtual museum presents even slightly more arousal and valence levels than the physical museum, although there exists a bias due to the novelty of VR. The result also supports the use of BR in emotion elicitation.

Another research by Jones & Alba (2019) focused on proving the effectiveness and learning outcomes of a 3D virtual museum. The results of their controlled studies proved that the immersive virtual museum was a comparable experience to the real-world museum tour in both knowledge learning and visiting satisfaction. They also explored whether visiting virtual museums ahead of visiting the same real-world museum could promote learning, and the results showed a positive effect. However, the result could also be caused by the Pre-training principles in Chapter 19.

Other research also evaluated participants learning outcomes, using experience and cognitive perception. However, these studies do not come with controlled studies; instead, they directly use evaluating forms and achievement tests to assess the absolute result or conduct within-subject studies. All the research results show that participants had a favorable opinion of the immersive virtual museum and believed that virtual museums could effectively promote learning outcomes. Except for the research conducted by Cecotti et al. (2020), other research (Ismaeel & Al-Abdullatif, 2016; Liu et al., 2021; Kampouropoulou, 2009; Ulusoy, 2010) is conducted with low immersive virtual museums.

Research results on this topic show immersive virtual museums' ability to arouse participants' engagement, build emotional connections, and promote learning, sometimes even as good as what real-world museums can provide. They also show that immersive virtual museums can be a reliable alternative when visiting real-world museums is impossible. However, the topic is still limited to trying to make immersive virtual museums as real as physical museums. Virtual reality can provide museums with a completely different way to communicate with audiences and nowadays many museums have applied VR to create not just a replica of the physical museum but new exhibitions with a lot of interactions and imagination. There is still a lot of space for research in this area. Also, the quality of research in this area varies. There are many studies that come without comparison studies and only use self-report questionnaires for evaluation.

Value-Added Research

Value-Added Research focuses on determining which features in immersive virtual reality influence users' learning outcomes and cognitive experience. Studies on this topic can help derive design principles to improve immersive virtual museums experience. In Chapter 24 of the textbook, the author examines how principles of multimedia learning can be generalized to learning in immersive learning environments. The result shows that except from the Redundancy principle, Signaling principle, and Imagination principle, Can immersive virtual museums, as an extension of immersive learning environments, also adopt these principles? In this literature

review, four studies are involved, most of which focus on principles based on social cues, especially the embodiment principle.

In The work of Chittaro et al. (2004), the researchers aimed to prove the effectiveness of guided tours in immersive virtual museums. The results confirmed that embodied agents positively influence learning outcomes in the context of presentations and can make the virtual museum more lively and attractive for the user. However, some users complained that the unnatural walking and talking speed and the unhuman like the appearance of the guide had influenced the visiting experience, following the embodiment principle and the image principle.

In the work of Sylaio et al. (2019), the researchers assess how the status of virtual guides in the immersive virtual museums influences the credibility of their storytelling and the emotions they evoke to virtual visitors. Specifically, they compared three different high-detail human avatars narrating the story of one exhibit: a female curator of the exhibition; a male museum security guard of the exhibition; a female visitor of the exhibition, and found that the narrator who is closer to the status of the visitors elicit stronger personal emotional involvement and shows higher credibility. However, this research did not come with an achievement test about the learning outcomes.

Bönsch et al. (2021) examined whether users prefer visiting an immersive virtual museum with a virtual guide or a free exploration accompanied by an embodied conversational agent (ECA) based on Q&A. The participants' visiting experience questionnaires showed no preference between a guided tour and the ECA tour. A possible explanation might be that although participants enjoyed the free exploration and that the ECA was able to determine their

interest correctly, it felt unnatural to "walk" with the ECA during the exploration. It might be the result of the redundancy principle (Chapter 16) that too much redundant accompanied resulted in negative influence.

The study of Sundar et al. (2015) focused on a different topic. They evaluated whether the three affordances of communication technology—customization, interactivity, and navigability can help ensure an enjoyable virtual museum visiting experience. They found that although each affordance was associated with distinct psychological benefits that led to a more enjoyable virtual museum experience, combining all of them on the same interface tended to undermine these benefits. This result might also follow the redundancy principle that too many add-ons might be distracting and diminish their individual benefits.

The research under this topic analyzes how different principles of multimedia learning can be applied in immersive virtual museums. Results mentioned in this literature review show that the embodiment principle, the image principle, and the redundancy principle work in this context. However, most of the research does not use achievement assessments to evaluate participants learning outcomes but uses self-report questionnaires to evaluate their visiting and learning experiences. Also, future research on other principles should also be involved to understand the principles in learning in immersive virtual museums fully.

Limitations

More solid research is needed to better understand what, when, why, and how immersive virtual museums can help.

Firstly, more research should focus on the boundary conditions of immersive virtual museums, such as on which types of subjects, what group of the age, and other users' characteristics, including the prior knowledge, cognitive load, and navigation ability.

Secondly, more studies should evaluate participants learning outcomes based on the achievement assessments and compare them with controlled groups instead of just using self-reported questionnaires about the visiting experience for more persuasive and reliable results.

Thirdly, although there are studies comparing immersive virtual museums with conventional media, there is almost no attempt to compare different types of immersive virtual museums. For instance, does the immersive virtual museum have a more positive effect on learning outcomes when displayed with HMDs than with desktops? Does the immersive virtual museum constructed with Quicktime VR perform better than the one constructed with 3D modeling? Also, other principles of multimedia learning should also be evaluated in the context of immersive virtual museums. These types of research can also help conclude the design principles of immersive virtual museums.

Conclusions

Through this literature review work, I would conclude that there is a trend of promoting visiting immersive virtual museums but without a solid rationale behind it. It is good to see the growth of the number of research on this topic in the recent year. This literature review briefly overlooks these previous works and tries to tackle some fundamental research questions in this area. As mentioned in the first section, there are three questions we would like to address in this

literature review. The first question is: What does visiting an immersive virtual museum mean to users based on cognitive theory? Based on the Method Comparison Research, it can be concluded that visiting immersive virtual museums can arouse participants' emotions similar to the similar degree of physical museums and promote visitors' engagement. It is reasonable to regard immersive virtual museums as a reliable alternative to physical museums when visiting real-world museums is impossible.

The second question is: What does the research evidence say about the effectiveness of immersive virtual museums on visitors' learning outcomes? Based on results of the Media Comparison Research, 3D immersive virtual museums have been proven to promote learning outcomes better than traditional methods such as 2D virtual museums based on text, images, and videos, and traditional history classes with PowerPoint. One result of the Method Comparison Research also shows that visiting immersive virtual museums ahead of visiting the same physical museum can promote learning outcomes.

The third question is: How can we design these immersive virtual museums to promote learning better? Based on the results of the Value-added Research, the existence of a virtual guide can promote visiting experience, and the effect would be more positive when the virtual guide is realistic, has a closer status to the visitors, and only appear when necessary. Also, if too many add-on features are implemented in one interface, their individual benefits will diminish.

References

Ambusaidi, N. A., & Al-Rabaani, A. H. (2019). The efficiency of virtual museum in development of grade eight students' achievements and attitudes towards archaeology in Oman. *International Journal of Educational Research Review, 4*(4), 496-503.https://dergipark.org.tr/en/pub/ijere/article/628304

Bönsch, A., Hashem, D., Ehret, J., & Kuhlen, T. W. (2021, September). Being Guided or Having Exploratory Freedom: User Preferences of a Virtual Agent's Behavior in a Museum. In *Proceedings of the 21st ACM International Conference on Intelligent Virtual Agents* (pp. 33-40).https://dl.acm.org/doi/abs/10.1145/3472306.3478339

Bowen, J. (2000). The virtual museum. *Museum International, 52*(1), 4-7.https://www.tandfonline.com/doi/abs/10.1111/1468-0033.00236?casa_token=rLzeq2FX1NsAAAAA:3_-rvgnOFQdoftT_EberRcH_QHR95cnzkKZqxVXfsCOy34s8GhXnj8bi0TCV0ciA-lvlbQwNe3Y

Cecotti, H., Day-Scott, Z., Huisinga, L., & Gordo-Pelaez, L. (2020, June). Virtual reality for immersive learning in art history. In *2020 6th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 16-23). IEEE.https://ieeexplore.ieee.org/abstract/document/9155108

Chittaro, L., Ieronutti, L., & Ranon, R. (2004). Navigating 3D Virtual Environments by Following Embodied Agents: a Proposal and its Informal Evaluation on a Virtual Museum Application. *PsychNology J., 2*(1), 24-

42.https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.98.137&rep=rep1&type=pdf

Crowley, K., Pierroux, P., & Knutson, K. (2014). Informal learning in museums.https://www.cambridge.org/core/books/abs/cambridge-handbook-of-the-learning-sciences/informal-learning-in-museums/9E378A5A2962278620FEEDF38E64CA4D

FRANCESCHİ, R., & DE MİGUEL, L. (2021). Bibliographic review. Existence of virtual museums for educational purposes is applied to the professional environment. *Journal of Educational Technology and Online Learning, 4*(3), 464-474.https://eric.ed.gov/?q=museum+virtual+reality+learning&id=EJ1315689

Hendricks, Z., Tangkuampien, J., & Malan, K. (2003, February). Virtual galleries: is 3D better?. In *Proceedings of the 2nd international conference on Computer graphics, virtual Reality, visualisation and interaction in Africa* (pp. 17-24).https://dl.acm.org/doi/abs/10.1145/602330.602333

Ismaeel, D. A., & Al-Abdullatif, A. M. (2016). The Impact of an Interactive Virtual Museum on Students' Attitudes Toward Cultural Heritage Education in the Region of Al Hassa, Saudi Arabia. *International Journal of Emerging Technologies in Learning, 11*(4).https://www.researchgate.net/profile/Ahlam-Al-Abdullatif/publication/301238741_The_Impact_of_an_Interactive_Virtual_Museum_on_Students'_Attitudes_Toward_Cultural_Heritage_Education_in_the_Region_of_Al_Hassa_Saudi_Arabia/links/5d1c9a01299bf1547c933711/The-Impact-of-an-Interactive-Virtual-

Museum-on-Students-Attitudes-Toward-Cultural-Heritage-Education-in-the-Region-of-Al-Hassa-Saudi-Arabia.pdf

Jones, G., & Alba, A. D. (2019). Reviewing the effectiveness and learning outcomes of a 3D virtual museum: A pilot study. In *Virtual Reality in education: Breakthroughs in research and practice* (pp. 52-75). IGI Global.https://www.igi-global.com/chapter/reviewing-the-effectiveness-and-learning-outcomes-of-a-3d-virtual-museum/224690

Kampouropoulou, M., Fokiali, P., Efstathiou, I., & Stefos, E. (2013). The virtual museum in educational practice. *Rev. Eur. Stud., 5,* 120.https://www.ccsenet.org/journal/index.php/res/article/view/28225

Katz, J. E., & Halpern, D. (2015). Can virtual museums motivate students? Toward a constructivist learning approach. *Journal of Science Education and Technology, 24*(6), 776-788.https://link.springer.com/article/10.1007/s10956-015-9563-7

Kostoska, G., Baez, M., Daniel, F., & Casati, F. (2015). Virtual, remote participation in museum visits by older adults: a feasibility study. *In 8th International Workshop on Personalized Access to Cultural Heritage (PATCH 2015), ACM IUI 2015* (pp. 1-4).https://re.public.polimi.it/handle/11311/1029187

Liu, Q., Liu, M., Yu, S., Ma, J., Liu, J., & Jiang, Y. (2021, August). Design and Implementation of Virtual Museum Learning Environment from the Perspective of Multimedia Learning Theory. *In 2021 International Symposium on Educational*

Technology (ISET) (pp. 266-269). IEEE.https://ieeexplore.ieee.org/abstract/document/9546571/authors#authors

Marín-Morales, J., Higuera-Trujillo, J. L., Greco, A., Guixeres, J., Llinares, C., Gentili, C., ... & Valenza, G. (2019). Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum. *PloS one, 14*(10), e0223881.https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0223881

Mayer, R. E. & Fiorella, L. (2022). *The Cambridge handbook of multimedia learning* (3rd ed). New York: Cambridge Univerisity Press.

Ulusoy, K. (2010). NOTE FOR EDITOR: Open Education Students' Perspectives On Using Virtual Museums Application In Teaching History Subjects. *Turkish Online Journal of Distance Education*, *11*(4),36-46.https://dergipark.org.tr/en/pub/tojde/issue/16910/176374

Sundar, S. S., Go, E., Kim, H. S., & Zhang, B. (2015). Communicating art, virtually! Psychological effects of technological affordances in a virtual museum. *International Journal of Human-Computer Interaction*, *31*(6), 385-401.https://www.tandfonline.com/doi/full/10.1080/10447318.2015.1033912

Sylaiou, S., Kasapakis, V., Dzardanova, E., & Gavalas, D. (2019, June). Assessment of virtual guides' credibility in virtual museum environments. In *International conference on augmented reality, virtual reality and computer graphics* (pp. 230-238). Springer, Cham.https://link.springer.com/chapter/10.1007/978-3-030-25999-0_20

Zouboula, N., Fokides, E., Tsolakidis, C., & Vratsalis, C. (2008). Virtual reality and museum: an educational application for museum education. *International Journal of Emerging Technologies in Learning (iJET)*, 3(2008).https://www.learntechlib.org/p/45198/

Zouboula, N., Fakides, M., & Tsolakidis, C. (2008, September). Educational uses of virtual reality: Constructing a VR museum. *In International Conference on Interactice Collaborative Learning Proceedings* (pp. 24-26).https://www.researchgate.net/publication/287645494_Educational_Uses_of_Virtual_Reality_Constructing_a_VR_Museum