Virtual Museum of STEM

Pedagogical guide on virtual museums and their benefits for STEM

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Part 1: Introduction to virtual museums and theoretical educational advantages

Introduction to the project: virtual museums as a tool for learning and benefits for education

The most recent PISA test results (2018) show that students, in the vast majority of European countries, have persistent difficulties with STEM subjects. Poor performance of students in mathematics has been constant for years and has even increased in science. Given the persistence of these undesirable results, a paradigm shift in the teaching of these subjects is imperative. We need to understand the factors that contribute to students' lack of motivation in these areas and develop tools to help combat the negative perception they have of them. STEM subjects are perceived by students as difficult and too abstract, which makes many consider them as "a hopeless case". It is particularly for students who are struggling with school failure. It is essential to make STEM subjects more concrete and closer to the students and the key may lie in more interactivity and in combining teaching with playful moments. The development of strategies to engage all students, adapting to their learning rhythms, became even more pressing in the context of the lockdown imposed by Covid-19. Students who already had learning difficulties were the most affected, both because it was complicated for teachers to have the necessary feedback, and because it was difficult to adapt teaching to the specific pace and needs of each student. There was a great effort, from the teachers, to try to make the classes more engaging and interactive, while giving more autonomy to the students, to minimise the risk of dropping out of the virtual classes. The work became complex, considering the lack of tools at their disposal. In this context, the need arose to create a tool that would allow greater autonomy and interaction in learning. To achieve this goal, this project aims to create the first virtual museum for STEM, in the area of education at secondary school level and suitable for inclusive education, accessible through any web browser (and not limited to virtual reality), to ensure that everyone can access.

As argued by Ribeiro, A., Silva, B. (2009), the advance of technology and concretely the advance and democratization of internet access defined, at the end of the 20th century, new forms of communication and interaction between people, and between people and institutions.

A virtual museum is an emerging concept that may structure ambitious educational projects. “A virtual museum is a digital entity that draws on the characteristics of a museum, in order to complement, enhance, or augment the museum experience through personalization, interactivity and richness of content” (VIMM, 2018). Bernard Deloche (2001) explores the concept of the museum as the privileged place to develop sensorial experiences. This concept can be exploited with significant benefits in the educational context. The use of interactivity elements, which involve the visitor, is the great potentiality of virtual museums. For Pallokas, I., Kekkeris, G. (2008), the advantage of digital support is the ability to aggregate several types of languages (texts, sounds, static and dynamic images). This methodology is quite adequate to the field of education, especially when new teaching methods are sought, replacing traditional ones, new learning strategies are explored and integrated learning approaches are valued. Student motivation is an essential factor for success at school, so the use of technologies, which are currently their major cultural reference, may contribute significantly to awakening enthusiasm for learning. A museum can be perceived as an education and training centre, due to its live, natural and visual materials. Using museums for educational purposes includes the synergy among educational process, pedagogy, museum art and psychology. Virtual museums are known for their communicative, educational, aesthetic and motivational characteristics. According to Pallokas, I., Kekkeris, G. (2008) a virtual museum is a type of website, where art objects, historical exhibits, collections or displays can be observed, giving the opportunity to create an educational process on a specially designed platform. A museum based on web technologies surpasses traditional museums in the highest levels of physical security, maintenance and other problem-solving procedures.

The use of a virtual museum can take place in a classroom, with the teacher guiding the students to the most relevant points, but it is also important that the students make the virtual visit themselves, to explore and analyse what interests them. The

teacher can prepare a guide to help students navigate, so that they can see the points to which they should pay more attention, but it is important to understand what caught their attention in the first place. Students have the chance to visit collections and get to know more about them, exchange ideas and share common experiences in an enjoyable game-like environment.

It becomes obvious that virtual museums are a functional communicational centre. That is, it gives anyone a chance to gain new knowledge and skills.

How technology can shape active participation and lifelong learning in STEM education

Technology can be considered a fundamental element of science, technology, engineering, and mathematics (STEM). It contributes to the implementation and design of the STEM pedagogy in several ways, and two outlines are further portrayed when the use of technology is considered for STEM education: 1. An embedding and direct integration of technology into the STEM pedagogy and 2. Use of technology as a tool or implementor to enrich the STEM pedagogy. When technology is integrated into Science, Engineering, and Math, students use technology to find solutions to problems in a challenging and creative method. Hence, the use of technology empowers students to develop creative thinking skills, problem-solving skills and become innovative while they shape active participation and lifelong learning in STEM education. The students can engage in virtual worlds or simulations through the use of several technology applications. Furthermore, technology-based education helps students progress in specific forms of literacy and skills such as critical thinking, social, and problem-solving skills, as well as technological literacy (Dogan & Robin, 2015).

Source: https://unsplash.com/

The extent to which different technologies engage students in thinking through composite concepts

helps them develop a deep knowledge of STEM. Moreover, it is important to note that the effective use and incorporation of technology is essential for the improvement of STEM learning, and this is fundamental to improving further the curriculum and student outcomes. Technology enables creative, purposeful, flexible thinking and knowledge development within the classroom, and it also broadens the "reach" of educational opportunities for students. The rapid development of technology and evolvement of its implementation increases the potential of using educational technology for the improvement of STEM learning outcomes. In fact, the students of the 21st century should set learning goals, which helps them be more conscious of the learning that they are expected to experience. This awareness helps students be more engaged, especially when different modernized teaching approaches methods, such as online interactive learning, simulation tools, Augmented Reality and Virtual Reality tools, and video games are included. (Vahidy, 2019).

Shaping active participation and lifelong learning in STEM

The high percentage of underachievers in subjects such as mathematics and science (PISA, 2018) recommends an establishment of modernized spaces where students can learn and enjoy STEM subjects. This establishment gradually introduces relevant STEM approaches that expose students to the terminology, notions, and experiences while preparing educators to support this goal. When technology is developed, having in mind both students and educators, and with special particular attention to the learning and teaching content, then both the students and the educators' benefit. In particular, engaging students in STEM approaches lays a foundation for future successful STEM learning. The use of technology in STEM education supports the above goal (Vahidy, 2019).

Consequently, the rise of STEM education offers an opportunity for the academic community to better define the portrayal of technology within the outline of STEM education. Encouraging reliable STEM engagement between students is important not only in preparing students for future careers in STEM, but likewise in

strengthening students with 21st-century skills in general. To support student engagement in reliable STEM practices, learning tasks should consist of the use of STEM-precise tools and technologies.

With an extensive range of technologies available for lifelong learning in STEM, it is significant to encourage educators to be critical consumers of technology, rather than focusing on which technologies to select, educators should instead concentrate on how they are being used in the classroom based on their alignment to the anticipated learning outcomes (Ellis et al., 2020).

Creating an online museum: how it has already been used and how it can improve

The first museum webpages were created in 1991, which provided a basis for the beginning of virtual museums. As with the internet there has been an acceleration of information exchange, private virtual museums have been developed in order to satisfy the changing needs. The Louvre Museum is one example, launching their virtual museum in 1994. Online museums became a sensation very quickly because of the novelty: “It was fun to be experimenting with a new medium. I can still remember the feeling I had when I realized that our online audience exceeded our physical audience.” (Semper 2020 in personal messages with the authors of “Museum Websites of the First Wave: The rise of the virtual museum” about the early years of the Exploratorium website).

There were a few challenges initially with the virtual museums because of the technological limitations of the time, they were often very simple, as Rob Semper states: “When we launched our website on December 15, 1993, we could see about 600 websites (overall in the web). One was the UC Berkeley’s Museum of Paleontology which had a site with some text and photos posted. Another One was the Library of Congress in Washington DC which was hosting an exhibit ROME REBORN: THE VATICAN LIBRARY & RENAISSANCE CULTURE which had an online version. We did not see any others” (Semper 2020 in personal messages

with the authors of “Museum Websites of the First Wave: The rise of the virtual museum”).

Virtual museums are not a new phenomenon nowadays, but it is increasing in importance in recent years because of its convenience, practicality, and innovative aspect. The way that museums interact with audiences are changing, therefore it is crucial to adapt strategies. The Covid-19 pandemic also impacted the development of virtual museums. It propelled the usage of virtual environments for education and leisure.

Learning and teaching processes started being carried out online, the digital transformation was accelerated, and it created new demands. Now teaching and learning is almost unthinkable without technologies.

But the challenges of this rapid change prevail, there is a difference between regular distance education and emergency distance learning. While regular distance learning requires careful planning and design, emergency distance learning is an alternative process that can be often hurried because of the sanitary crisis (Torres Martín, C., Acal, C., el Homrani, M., & Mingorance Estrada, N. 2021).

Although, new methodologies have arisen and with it the need to adapt, this change happened very fast leaving behind advances made previously in inclusion. The digital transformation allows the surge of innovative pedagogical methodologies that may reach a broader public and help improve the quality of education.

Virtual museums often have a physical museum with objects and artefacts, but this idea is progressively changing. According to Carly Straughan in the article “Is the future of museums online and what might a virtual museum look like?” she says: “It may surprise you to know that there are a number of resources online that consider themselves museums and have similar missions to, what most people would

consider, a museum. And most importantly they definitely fit our definition put forward by the Museums Association earlier."

Virtual museums are a form of motivation to incentivize learners to interact with objects and artefacts as a contrast of a physical museum where they often cannot touch anything. Another important advantage of virtual museums is that learners can stay as long as they would like. Furthermore, virtual museums allow people who cannot visit physical museums for any reason to have the experience of visiting a museum. With time, computers have become more flexible and widespread allowing users to move it and adapt their use to their needs more easily. With this increased flexibility virtual museums allow a more important adaptability to several types of users to have access to its content.

Virtual environments, especially museums ensure active learning with the student being autonomous and independent in their learning process.

Virtual museums promote self-learning while respecting different learning styles and pace, while motivating the user to learn because of the fun aspect of this tool.

Part 2: Existing experiments and uses of virtual museums or learning environments in education

Virtual museums as a tool for learning: how virtual environments help improve students' engagement and active participation

The traditional classroom environment tends to place students in a more passive role, with adults directing the learning. Dalgarno and Lee (2010) noted that different virtual environment platforms could be used for various educational purposes. Education has the opportunity to move beyond traditional classroom-based learning by embracing new and modern technology. In other words, a 3D environment offers a unique set of characteristics from a pedagogical and didactical point of view.

Virtual learning environments are primarily made for online learning, games and showing something we can't see in real life (simulations). As Barney Dalgarno and Mark J. W. Lee stated: "A 3-D virtual environment (3-D VE) can be defined as an environment that 'capitalises upon natural aspects of human perception by extending visual information in three spatial dimensions" (Dalgarno and Lee, 2010). When new technology is brought into educational activities, it is important for instructors to know all the possibilities for action that technology can offer and how learners could use it (Qian, 2018).

Educational institutions and educators are aware of the benefits of using a 3D virtual environment for teaching and learning. A 3D virtual environment enables exploring, learning, and constructing and manipulating virtual objects (Dalgarno and Lee, 2010). According to this, using a 3D environment in schools offers a series of challenges and potentials. Virtual environments provide more possibilities for student-centred learning, as they motivate students, help improve their engagement and active participation. Students can interact with their virtual environment to discover and experience locations and situations, solve problems and learn to think critically. "Simulations can also allow learners to practice skills or solve problematical tasks. This is particularly appropriate when the tasks involved are expensive and

dangerous to undertake in the real world" (Dalgarno and M. J. W. Lee, 2010). Using 3D simulations to train astronauts to repair a space telescope is one example of this kind of task (Psotka, 1995; Moore, 1995, in Dalgarno and Lee, 2010).

Virtual environments can be used to simplify learning tasks. They can be used to facilitate experiential learning tasks that would be impossible to undertake in the real world, to facilitate learning tasks that lead to increased intrinsic motivation and engagement, but also to facilitate learning tasks that lead to improved transfer of knowledge and skills to real situations (Dalgarno and Lee, 2010). Most importantly, 3D virtual environments can allow learners to communicate but also to undertake tasks together. It is known that cooperative and collaborative learning strategies should involve activities and tasks that entail positive interdependence between participants. Furthermore, each member makes a unique and valued contribution through their task responsibilities.

Research findings have shown that virtual learning is more convenient, encourages autonomy and increase the fun element of education (Bakshio, 2021). Through direct engagement with virtual worlds, educators have the opportunity to present environments for learners that break barriers such as shyness, embarrassment, lack of social skills and disabilities. Also, students can simulate scenarios from everyday life, from some significant historical events, and scientific experiments – all that by using virtual environments. In other words, they have a chance to learn more by using something new and modern that aren't books and lectures. Accordingly, Carter (in Franks, 2016) talks about Virtual Harlem, a learning environment that allows students to experience the Harlem Renaissance from the early 20th century. Virtual Harlem enables students and other interested people to travel back to see historical figures from that period and hear music and interviews from that time (Franks, 2016).

Based on research (Becker Nunes et al., 2019), we can see that virtual environments have an essential role in variant types of learning. The teacher is the one who creates learning materials and situations during different pedagogical and didactic activities in the virtual world—because of that, being a teacher is one of the most critical roles in the whole process of virtual learning.

Virtual environments also provide and support students with disabilities to join in everyday learning. In education, virtual simulations can be used to provide authentic personalised learning platforms customised to meet the unique needs of each user. It helps students with their social skills, allows them to stay organised, and creates opportunities for success.

Based on a case study (Qian, 2018) for middle–school students to learn about complex causality in the ecosystem, virtual simulations can help students understand that organisms too small to be seen can play a fundamental role in the ecosystem. Also, students can explore a large area – a significant feature for ecosystem education – in order to understand the effects over distance (Qian, 2018).

Another example of virtual world technology, Google virtual reality, gives classrooms the ability to attend virtual field trips. The possibilities for the use of virtual world technology are endless. For example, using Google Glass, students can virtually visit some museum or other digitally based cultural space. "The Museum" is a place where we connect to the subject matter it presents, and it encourages us to learn more about it. A good museum exhibit can motivate us to get a book on the subject, talk to knowledgeable people, think further, and be self-directed learners.

Also, by using Google's virtual reality and Google Class (3D device), students can have unique experiences that are complicated to have in real life. For example, they could interact with the stars, go to some specific place, and so on. The use of Google Glass and Google virtual reality enriches students' learning and gives teachers another pedagogical and didactical tool for teaching (Franks, 2016). For example, The National Gallery in London offers a lot of links to at-home resources: videos, story features, virtual tours and so on, so learners can see and learn about art and history from home or school.

One more example of virtual world technology is Syracuse University's virtual reality lab, known as MarkerSpace. This lab is a collaborative space to imagine, design, build, teach and learn. Students learn and interact with objects they create. It is virtual reality that brings social object elements into real-world learning environments. Using 3D printers, students then have the opportunity to print their objects for later overview. For example, viewing an exact copy of the school of

Athens in a digital museum, then printing out a copy of any part of the exhibit for later study. Such tactile experiences add revolutionary social interaction between cultural resources and those who created them (Franks, 2016).

According to Matsui (in Qian, 2018), one more advantage of virtual learning environments can be seen at the beginning of virtual exchange in strengthening interpersonal emotional connections between users and their partners. For example, two Japanese and two American students participated in various designed virtual environments but used the same 3D virtual application (Matsui, in Qian, 2018). The results show that users are prone to anxiety and trying to find avatars that help avoid long silences. The final results show that the effect was more substantial at the beginning of sessions, and as the sessions continued, the effect gradually reduced (Matsui, in Qian, 2018)

There are a lot of options in digital learning environments which can be used for pedagogical purposes. Besides planning teamwork and sharing data resources, examples of mentioned purposes can also be using a chat and other communication tools for discussion and brainstorming. Future digital systems may need to fit those purposes and ideas, but also to offer modern and innovative solutions to help in new learning, sharing and communicating.

When more is learned about the virtual environment generally, such an environment will be suitable for teaching and learning in a pedagogical sense (Dalgarno and Lee, 2010). Virtual worlds in education can improve motivation, engagement and also reach more students with diverse learning styles than traditional methods.

A study of student motivation and perspectives found that students were very interested in virtual learning (Qian, 2018). Furthermore, the opportunity for students to take on scientific roles in virtual learning supported identify exploration, particularly self-efficacy-believing in their ability to succeed in investigating problems in science (Qian, 2018). Furthermore, personal satisfaction, communication skills and engagement were examined as emotional and mental achievements and the outcome of using a virtual environment.

Virtual environment and learning are crucial as alternative education during epidemics. The use of technology dominates today's classrooms, and future generations will be even more comfortable with using technology at all levels of education.

Virtual museums around Europe

The concept of a museum is no longer what it was in the past, although the main types of museums, according to Pescarin, S. (2014), quoting EGMUS Definition and Explanation, are pretty much the same and can be summarised in three main categories: Art, archaeology, and history museums; Science and technology museums; and other museums. Nowadays, there is a recognition that museums are not just a place to display objects or artworks, to study or conserve them. The idea of a museum, whose goal is just the presentation or study of its collection is no longer feasible, if ever. To capture public's attention, 21st century museums have to focus on communication and attraction, enriching the visitor experience. To make the experience of visiting a museum enjoyable, museums have to divide complex information into small or synthesised parts. For today's pace, the public cannot lose time standing in front of an object for a long period. Either they get an immediate answer to their questions, or they will be captured by some other information and proceed. To be more attractive and capture the attention of the public, museums are resorting more and more to new technologies.

Contrary to general perception, museums are a "relatively recent institution and only in the second half of the XX century the basic principles of contemporary museums were stated: museums should be able to elastically "bend" and become a privileged tool for communication[1], assisting the cultural experience and, whenever opportune, making use of technologies and

wide spectrum systems" (Carrozzino, M. & Bergamasco, M. 2010). Today, more than ever, they make perfect sense in the dynamic museums need to create with the public, establishing a communication that must be rich and captivating. The main and most important technology used by museums, especially regarding their relationship with the public, is the internet. The internet has revolutionised the way people communicate, and this is no different in its relationship with museology. Museums, like any other institution, are now present on the World Wide Web. "The creation of websites for museums proliferated from the 90's onwards, with the advance of the internet, but some museums still don't even have institutional websites. And many of them have sites whose sole purpose is to provide contact information of the institution"[2] (Henriques, R., 2004). In 2020, however, there was a boom in the number of museums that shared their content online, as they had to close their doors due to the COVID-19 pandemic.

The Internet enables virtual visits, which may attract more public to the "real" visit. In other words, more than serving as a showcase of the museum's business card, the Internet enables access to their showings in a broader way. Therefore, museums may bring to the general public information about the content of their collection and the cultural activities developed in their premises. Thus, the use of the Internet as a means of dissemination and communication has enabled museums to have greater interaction with users. Can we then characterise the different types of museum sites according to their relationship with the Internet and new technologies? Piacente, M. (1996), in her thesis "Masters of Arts in the United States", quoted by Henriques, R. (2004), lists three categories of museum sites: electronic booklet, museum in the virtual world and really interactive museums.

The first category of museum sites is the electronic booklet, whose sole purpose is self-presentation. This type of website works as a communication and marketing tool. The user has access to the history of the museum, opening hours and, sometimes, to the technical staff of the museum. It is the most common type in almost all museums. Some are more elaborate, depending on the available resources, but all have as main goal to be a visual presentation, like a booklet. In this case, the Internet works as a way to make the museum better known and also to enable easier access by users of the World Wide Web. The choice of more elaborate

sites, both in terms of design and navigation, depends on the human and financial resources available to the institution. The maintenance costs of a simpler site, which does not need a database, can be supported by any institution, because there are servers that offer free hosting for this type of site. It is possible that the choice of this simpler type of site depends more on the type of resources than on a decision by the institution.

The second category of site would be the museum in the virtual world, that is, in this type of site the institution presents more detailed information about its collection, often through virtual visits. The site projects the physical museum virtually and frequently presents temporary exhibitions that are no longer available for viewing in its physical space, making the Internet a kind of technical reserve of exhibitions. Many of them can also provide databases of their collections, showing objects that are not on display at that moment, or providing information on a particular subject. It may be possible to view objects in 3D and buy products online from the museum shop, that is, the site also provides an e-commerce service for the museum.

The third category is really interactive museums. In this type of site, there may even be a relationship between the virtual museum and the physical museum, but elements of interactivity are added, which involve the visitor. Sometimes the museum reproduces the exhibition contents of the physical museum, and, in other cases, the virtual museum is quite different from the physical museum. What makes these museums interactive is the way they work with the public. Interactivity is the soul of this type of museum site because it allows the public to interact with the museum. It is important to point out that the museum on the Internet does not lose its essential characteristics but may acquire new facets. In other words, the objectives of the site are not necessarily different from the physical museum, but a complement to it. This category of site is actually a virtual museum and not just a site.

The museums that know how to take advantage of all the possibilities that the Internet offers, creating their own virtual museums, manage to go beyond their borders. The possibility of greater interaction with the public is the main advantage of creating virtual museums, whether they are virtual representations of existing museums or created especially for the World Wide Web. At this point, it is important to mention the different dimensions of virtual museums. In the words of Henriques,

R. (2018): "Regarding the concept of virtual museum, we must clarify that the virtual museum may have two configurations: virtual aspects of a certain physical museum or essentially virtual museums. In this case, the existence of a virtual museum does not imply the existence of a physical museum"[3]. In essentially virtual museums, their activities (museological actions) are mostly carried out in their virtual space, i.e., it is not a museum to be visited by the public in its physical space. This does not invalidate that some museological actions occur outside the virtual space, but the essence of these actions is concentrated in the virtual space. In the case of virtual museums, as a complement or replica of the physical museum, museological actions are worked in both ways, making the museological process quite enriching, because the public will have two different approaches to the same collection: a presential approach and a remote approach.

Considering what has been exposed, we will analyse, now, five of the main virtual museums across Europe and their technological options, that is, we will see if it is a virtual museum that replicates the physical museum, an essentially virtual museum (there is no attendance to the public in a physical space) or an interactive virtual museum:

THE BRITISH MUSEUM (London, England)

www.britishmuseum.org

The British Museum, founded in 1753, was the world's first public national museum. It has one of the largest and most famous collections of antiquities in existence. Here you can discover two million years of human history and culture. Its collection consists of about eight million objects and includes world-famous objects such as the Rosetta Stone, the Parthenon sculptures and Egyptian mummies.

Virtual visits can be booked and visitors will be taught remotely by an expert from the British Museum. Through live activities, interactive quizzes and thought-provoking questions, visitors will enhance their knowledge and understanding of the past. This is a truly interactive museum, that helps visitors to develop their historical enquiry skills and specially challenge them to think critically.

MUSEI VATICANI - Vatican Museums (Vatican City, Italy)

www.museivaticani.va/content/museivaticani/en/collezioni/musei/tour-virtuali-elenco.html

The Vatican Museums are among the most important museums in the world. Several different buildings, which are interconnected, bring together one of the world's most fantastic and extensive collections belonging to the Catholic Church. They bear witness to humanity's artistic and spiritual aspirations and the search for the supreme beauty that finds its realisation in God. The Sistine Chapel is one of the sites that most interest visitors.

We can visit the space remotely as if we were on site. The image quality of the virtual museum is excellent. The visitor can interact with the exhibits by watching videos and reading additional information.

LOUVRE (Paris, France)

www.louvre.fr/en/visites-en-ligne

The Louvre is a universal museum, created in 1793. It is the largest art museum in the world and is located in the Louvre Palace in Paris. Its collections, among the finest in the world, span several thousand years and a territory stretching from America to Asia. The collections are divided into 8 departments and feature works admired all over the world, including the Mona Lisa and the Venus de Milo.

The virtual tour is very intuitive and we can walk through the museum galleries as if we were there. The fluidity of the transition in space is remarkable. We can interact with each piece, magnifying the image and reading more information about it. It is also possible to listen to a description by an expert guide and get help with navigation whenever necessary.

TEATRO-MUSEO DALÍ - Dalí Theatre-Museum (Figueres, Spain)

www.salvador-dali.org/en/museums/dali-theatre-museum-in-figueres/visita-virtual/

Dalí Theatre-Museum is a museum dedicated to Salvador Dalí and is located in his hometown, Figueres, in Spain. Opened in 1974, it was conceived and designed by the artist himself in order to offer visitors a real experience and draw them into his unique and captivating world.

The virtual visit to this museum is based on a 3D model of its interior. This way, we can have a global perspective of the space, which makes the navigation through it very simple and also very fluid. We can interact with each piece by clicking a button, which gives us more information about it. With the appropriate technology, we can make this visit in virtual reality (3D).

MUSEU CALOUSTE GULBENKIAN – Calouste Gulbenkian Museum (Lisbon, Portugal)

www.gulbenkian.pt/museu/colecoes/visita-virtual/

In this museum, located in Lisbon, you can get to know the collection of the philanthropist and art collector Calouste Sarkis Gulbenkian (1869-1955). The affection he had for objects and the quality criteria he used to follow can be seen in the phrase "only the best is good enough for me". This collection includes objects from various periods and areas. There are pieces of Egyptian art, Greco-Roman art, Islamic and Far Eastern art, from various areas, such as numismatics, painting and European decorative arts. In this museum, the virtual visit is made using a 360º image. The visitor has little way to interact with the space that surrounds him, being conditioned to the role of passive spectator, although dazzled. This is the typical virtual museum, which replicates the real museum.

Some of the mentioned museums are more interactive than others, however, they all provide a fabulous experience for visitors, mostly because of the richness and spectacularity of their exhibits and collections.

Added value of virtual environments in education in a distance learning context

According to Hawkey (2004), the rapid development and impact of ICT have created three different perspectives on e-learning within the education system. The primary is anxious almost exclusively with technical issues. The second sees ICT mainly as a way to deliver common content to a far wider audience faster. The third could be a catalyst for a fundamental reappraisal of the complete enterprise of education. Museums have a crucial role in enabling distance learning. As museums in education provide a distance learning context, where it is possible to learn from objects, not about things, as well as develop strategies for discovering information, rather than focusing on the presented information itself. Today, museums have reached different levels in the development of digital exhibitions and learning resources. This allows learning to be a process of active engagement with experience, in which learners can choose where and when they learn. A new way of learning is emerging, not necessarily better or worse, but certainly different. In this type of learning, students can be encouraged to upgrade their virtual experiences and to deal directly with authentic subjects. In this way, online museums offer a different and more exciting learning opportunity. A virtual visitor may understand the situation better and better interpret it when they see it. The application of digital technologies simultaneously enables an individual experience and offers options for social interaction that enriches learning.

According to Mamur and associates (2020), museums' digitisation method has evolved into video game and augmented reality applications that are reflected in numerous educational fields. For example, historians, curators, and archaeologists have started using video game technologies to market a deeper perception of historical reconstructions. Digitisation in educational contexts has provided the chance for real-time interaction. Visitors of virtual museums thus exchange their ideas and experiences in an exceedingly virtual environment. Digital access to educational content at any time from anywhere provides a spread of educational experiences, and this is often precisely the best impact of digital media during distance learning. Also, recent research on this subject shows that the employment

of digital technologies for distance learning encourages different age groups to go to virtual museums to facilitate their learning and to be told with understanding. Through a virtual museum, the virtual environment in education provides a different approach to learning and a different direction to digital content containing various complex data. From the perspective of education through the virtual museum internet provides multiple opportunities to accept, recognise, and understand interculturality and explore data that are no longer so accessible today because they are damaged, need reconstruction, or cannot be easily experienced. That is why virtual museums offer a new and different form of presentation and adoption of content. The way content is displayed through virtual museum technology allows visitors through various digital technologies and presentation forms to more easily adopt it. Such an approach to distance learning through virtual museums allows students to understand the content better and understand cultural differences and interactions to explore the historical and social context of specific content easily. In addition to the above, virtual museums are also characteristic precisely because they provide the ability to select individual learning characteristics as they allow learning through different cognitive styles and a constructivist approach to learning.

Ismaeel and associates' research (2019) reveal that students today, who are considered to be digital natives, are increasingly involved in digital technology, and ICT offers them a different approach to learning and education. Digital tools allow the possibility to look at the material as a product within a broader network of historical, cultural, socioeconomic, and geographic links, which fosters a better understanding and interpretation of the material. The authors of this study also state that the educational potential of virtual museums is generally recognised, although their use is still limited in a formal educational context. Furthermore, the authors argue that virtual museums are a robust ICT tool for enhancing learning and knowledge acquisition. They provide an interactive learning environment that suits learning styles and student interests.

The findings of different studies (Daniela, 2020; Hawkey, 2004; Ismaeeel et al., 2019; Mamur et al., 2020; Paliokas, 2008) emphasise the importance of the educational value of virtual museums for improving the educational process that complements the curriculum. Education through virtual museums is the future of the

educational process. It represents an opportunity for different learning and integration of students into the learning process by improving the learning experience.

Part 3: Possible applications of virtual museums to teach and learn about STEM

Virtual learning environments in helping the improvement of students' performance in STEM education

Virtual environments can be used in STEM: science, technology, engineering and mathematics (Cecil et al., 2013). It can be used in the STEM area by using simulations, different digital tools and various types of learning materials. Teachers and other education experts should use virtual learning environments to prepare participants (their students) for becoming competent graduates and quality employees.

Virtual worlds are proper virtual learning environments whose characteristics can be applied and used in different teaching and pedagogical areas. Teachers should know that the quality of teaching and learning requires understanding how today's students' generations are studying. Based on research (Becker, 2019), a group of sixth-grade students used a virtual environment for a few months, while their level of knowledge was rated through tests. Also, their learning styles were analysed, and the results have shown the potential of virtual worlds to adapt various learning styles and improve learning (Becker, 2019).

According to Cecil et al. (2013), virtual learning environments (VLEs) involve creating graphics-rich environments based on 3D technology that can also be linked to virtual reality technology. Virtual reality is described as a technology that allows the creation of a 3D simulation environment, where users can communicate using 3D glasses and tracking tools. Virtual reality and cyber computing techniques are some of the newer technologies being applied for educational purposes. There is significant potential in using such technology to teach complex and straightforward concepts in the STEM field. Virtual learning environments involve completely immersive environments in which reference to the real world is completely excluded. It includes

a virtual prototype, described as a three-dimensional (3D) computer model that attempts to mimic a target object or environment using virtual reality technology.

An integrated STEM learning environment is a learning context where learners learn more than one discipline and practice multi-disciplinary knowledge in solving a problem using technology (Yang and Baldwin 2020). The use of technology in the STEM field in general increases students' motivation to adopt and understand complex content and upgrades their experience and knowledge. In this way, digital technology helps contribute to active learning. According to Yang and Baldwin (2020), immersive and interactive technology (augmented reality and virtual reality) can provide students with feelings of immersion that improves students understanding and engagement in STEM subjects. This type of distance learning allows students to engage better in authentic learning and increases motivation. In addition, learning through play that includes the importance of mathematical engineering and technology contributes to making it easier for students to understand the complexity of these areas (Yang and Baldwin, 2020. according to Lemke, 2013).

Yang and Baldwin (2020) state that technology offers various opportunities for college students to find out about technology, and it encourages students to interpret scientific and mathematical ideas in a new way. Technology can make the exploration of STEM subjects possible and support students to attach different disciplinary ideas, for example, when using simulations. Yang and Baldwin (2020) present technology-use strategies for integrated STEM learning environments:

1. providing an authentic learning context (this is a teaching approach that allows students to apply knowledge to real-world problems);
2. offering a web-based inquiry environment (inquiry-based learning require making projections, investigation, assessments, as well as developing demonstrations, and a web-based platform can be used to provide the means for practice investigation and explanations while developing an understanding of scientific queries);

3. developing learning with immersive and interactive technology (immersive and interactive technologies, like simulations, provide an opportunity for students to experiment or investigate phenomena beyond physical constraints);
4. creating content (creating content with different technology creates an opportunity for students to present integrated STEM projects and provides the opportunity to play roles and actively engage in design challenges).

Yang and Baldwin also state, "The use of technology in integrated STEM learning environments can expand effective teaching and learning" (Yang and Baldwin, 2020). Categorising the technology-use strategies can help teachers adopt effective strategies to guide student learning in a STEM environment.

According to Daniela (2020), virtual museums can function as learning agents because it's possible to reinforce analogue reality with digital information; integration takes place in real-time and in an exceedingly coordinated way; they permit combining different resources like text, video, audio and 3D; they're interactive, and also the involvement of the individual is critical for the creation of the content. Furthermore, supported research (Daniela, 2020) the employment of technological solutions as agents within the training process helps students analyse, reorganise, assimilate, contextualise and synthesise their knowledge, providing new levels of thinking and learning. In such a way, individuals can use their smart devices to attach to the present knowledge, where education may be organised in a particular environment and under certain circumstances, which might not be possible without the utilisation of virtual solutions. Daniela (2020), in line with Fowler (2015), emphasises three stages of learning through VR, which will even be taken under consideration for virtual museums:

1. Conceptualisation: where the learner takes in and interprets different information and concepts;
2. Construction: where the learner assesses facts and concepts, interactively applies knowledge, analyses problems, observes real-life experiences by building on their own understanding of the experience;
3. Discussion: where the learner discusses what he has learned with others.

The emphasis is that information is obtained already within the primary stages of learning that the individual can then build their knowledge and apply it in new contexts.

Different studies have shown that video game incorporates a positive effect on student motivation for various learning activities (Daniela, 2020; Hawkey, 2004; Ismaeeel et al., 2019; Mamur et al., 2020; Nikoletta, 2008; Paliokas, 2008; Yang, 2020). Daniela (2020) states that considering learning in museums as a mode of active learning, the potential for virtual museums exists. In terms of the tutorial value criteria, virtual museums will be considered learning agents that stimulate interest, supplement existing knowledge with a new one, and provide a change in types of learning. Still, they will not be regarded as full-fledged learning agents which is able to replace the educators work entirely. Several reports (Cecil et al. 2013; Daniela, 2020; Yang and Baldwin, 2020) also state that the great potential of virtual learning environments and computer simulations involves and motivates students, especially in science, technology, engineering and mathematics.

Virtual learning environments as a support to educational needs and extraordinary circumstances

Source: https://www.cnm.edu/news/cnm-develops-workshops-to-help-k-12-teachers-create-successful-virtual-learning-environments

The Virtual Learning Environments encourage a positive learning setting along with student engagement and an environment that further benefits students from flexibility and access to a wider range of resources. For instance, this virtual learning is also called ‘just in time’ learning since it can take place anywhere, at any time, and is accessible in anyplace. The efficient use of new technology entails an evolution of the current pedagogy and a move towards cooperative and interactive teaching and learning activities. Like any technology, virtual learning environments, embed fundamental principles about teaching and learning (Maltby & Mackie, 2016).

Virtual learning environments as support to educational needs

A virtual learning environment is not a new experience in the education context. It is already being used in a number of schools as well as higher education institutions that have already applied such kind of software. Such a computer-assisted approach exposes new opportunities for both students and educators, while bringing some challenges. The key reason to implement new technology is to generate something better, faster, and at the same time simpler. Below you can find advantages and drawbacks of using virtual learning environments as a support to educational needs:

Flexibility:

Virtual Learning Environments transform the educational process into a more flexible learning approach, specifically in terms of time. Having a long-lasting and free contact to all the learning materials, students can easily coordinate their studies with further activities and plans. Consequently, students are free to work at their own pace and each student can read the content and watch the videos as many times as they wish in order to comprehend the topic. In contrast, students that are fast learners do not have to wait for the rest of the class to move further.

Accessibility:

Learning takes place online – in a virtual environment – thus there is no need for students to be present at a classroom. This forms a high-quality education accessible for disabled people as well as for those living in distant areas or even in other countries and continents. A virtual learning structure facilitates a continuous educational process as students may continue their studies while being on vacation or even when lying in bed with a cold, should they wish to.

Engagement:

A virtual learning environment is beneficial to experiments with content formats – such as blog posts, images, infographics, slide presentations etc. – as well as new approaches. The virtual learning environment encourages educational guidelines with online tests and quizzes, videos and presentations. A mixture of a number of distinct activities grands better student engagement and adds further gamification to the learning procedure.

Interactivity:

An essential requirement for a virtual learning environment is interactivity. It is not sufficient for material to be presented to students and then the students to be tested on it. The virtual learning environment should empower the students to reorganize the presented material, add their own resourced, marginalize the material, introduce and run simulations etc. Students should be active in shaping the 'world', rather than simply being passive observers of the 'micro-world' formulated by the educator (Britain & Liber, 2012).

Motivation:

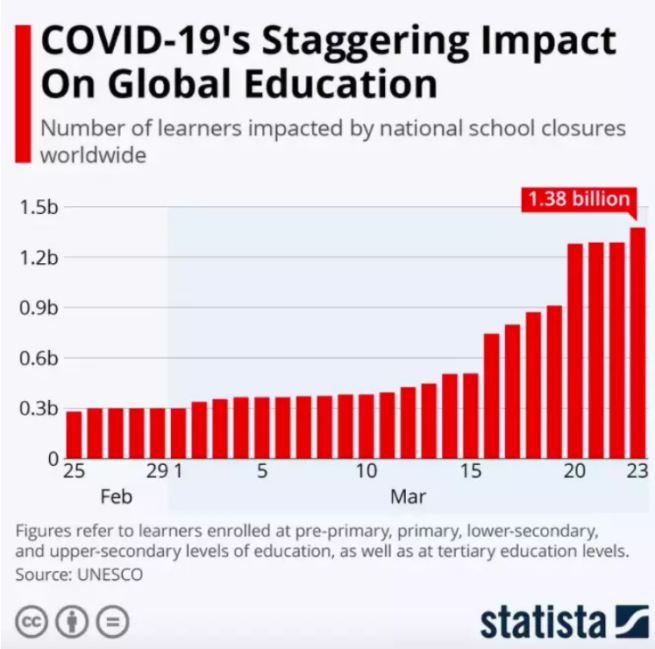
The flexibility formed in a virtual learning environment can be a problem for students who lack self-discipline or with low motivation. With no strict deadlines and no constant guidance, it is hard for students to remain concentrated and study productively. Correspondingly, the virtual learning environments create more opportunities for cheating since no one sees if the students are using other devices while having an online test or if they are truly doing everything by themselves. Thus, high motivation and self-discipline are critical in a virtual learning environment (Puzhevich, 2020).

Virtual learning environments can be analysed by the latter aspects:

- VLE is a designed information space
- VLE is a social space: education interactions occur in the environment
- The portrayal of the virtual information/social space can differ from text to 3D worlds
- VLE are not restricted to distance education: they also enhance the classroom activities
- VLE combine a variety of technologies and multiple pedagogical approaches
- A number of virtual environments overlap with physical environments

Online-based education is often correlated to distance education, even though it can be used extensively to support present learning. For instance, communication completed independently according to a person's own pace/schedule offers the students time flexibility. Many online-based courses merge distance and presence, making the learning environment more vigorous. In the past couple of years secondary schools have introduced internet-based activities, added to endow the face-to-face learning activities. This enhancement has been implemented in the educational system as an add-on or even as a stronger effect on the educators' pedagogical approaches (Dillenbourg et al., 2007).

How has COVID-19 affected the education system



The pandemic has effectively forced a world-wide shutdown of various activities (Adedoyin & Soykan, 2020). Additionally, it has led to the closure of schools all around the world, with billions of students (see figure below) trying to catch up with school from home to ensure educational continuity and scale down learning loss (McBurnie, 2020). Subsequently, the education system has changed completely, with a surprising increase of virtual learning environments, through which teaching is undertaken remotely and on digital platforms. This marks the largest 'online movement' in the history of education (Li & Lalani, 2020).

The COVID-19 crisis has activated a challenging change in the educational system, highlighting the great importance of adapting to new technologies. Virtual tutoring, video conferencing tools, and online learning software have been significantly demanded since Covid-19. In response to that, many online learning platforms are offering access to their services, supporting remote education. For instance, the Italian government created a website to support schools to activate different forms of distance learning during the closure period of the coronavirus emergency (https://www.miur.gov.it/web/guest/-/didattica-digitale-distribuiti-gli-85-milioni-del-decreto-ristori-firmato-il-decreto-con-il-riparto-per-singola-scuola). In addition, the Ministry of Education in Spain created a website call "Resources for online training" (https://intef.es/recursos-educativos/recursos-para-el-aprendizaje-en-linea/), in an effort of offering teachers and students access to different types of educational materials and training courses.

For ensuring continuity in education and training, the EU also developed a wide range of online learning platforms for teachers and educators. Learning Corner is an easily accessible platform with teaching materials, including online games, to help pupils of all ages discover the EU. eTwinning is another collaborative European platform for teachers to communicate, exchange opinions and resources, and co-create projects. There is sufficient evidence that online learning can be more effective in several ways for the students who have access to the 'right technology'. According to studies, pupils absorb 25-60% more material while learning online than only 8-10% when learning in a classroom. This is primarily due to the fact that students learn faster online, as the learning process is not as time-consuming as it is in the traditional classroom. Students have the freedom of going back and re-read difficult parts, thus adapting an individual way of learning, customized at their own space. (Li & Lalani, 2020).

Virtual learning environments are the future of education, not only for higher education but also for secondary education, where virtual learning has been introduced for good in the past year. The target of virtual learning environments is to enhance both the efficiency and the interaction between the students. These online-based systems are the fundamental tools to transform and refurbish the present educational system (Bri et al., 2009).

Virtual learning environments as a learning tool for all learners

Virtual learning environments can offer interesting opportunities to overcome a wide range of barriers. However, they are not magic tools that work the same way for everyone. To understand the opportunities offered by virtual learning environments, it is necessary to start by exploring what barriers exist.

Debunking the myth of the digital native:

The technological barrier to accessing virtual learning environments

The first barrier comes hand in hand with a myth, according to which all teenagers are now digital natives. The idea of this expression is that as youths were born when the internet was rather widespread, they have used digital tools since their childhood and naturally understand them (Tricot and Chesne, 2020), almost as if it was a natural biological process to them. A frequent saying is that today's youth was born with a smartphone in their hand.

While today's youth live more closely with technology than previous generations, transferring skills from a personal use of computers, smartphones or tablets to an academic or professional context is not a smooth trajectory. In other words, playing games or navigating on social media does not enable one to format a text document or to exchange emails efficiently. This skill gap has been at the core of the approach of several associations that accompany youths and those at risk of social exclusion in developing school and professional digital training during the 2020 lockdowns in the case of France (Tellier, 2020). Digital literacy does not come naturally to humans just yet.

Pixabay.com https://pixabay.com/photos/infant-to-learn-laptop-question-2709666/

The geographical, economic and social barriers to using virtual learning environments

If digital literacy is a skill that is developed and acquired and not a natural trait, it is no wonder that digital literacy levels can vary greatly depending on a wide variety of factors, including geographical, economic and social factors. This idea is contained in the definition of the digital divide of the OECD:

“The term "digital divide" refers to the gap between individuals, households, businesses and geographic areas at different socio-economic levels with regard to both their opportunities to access information and communication technologies (ICTs) and to their use of the Internet for a wide variety of activities” (OECD, 2006)

Therefore, the digital divide does not only consider differences in terms of access to technology but also in terms of proficiency or literacy. While the weight of each factor in contributing to the digital divide is not homogeneous depending on different regions, countries or contexts, it is interesting to note that what might be the key factor in motivating people to develop new digital skills would be the importance of such skills to their social group (Vodoz, 2010). The consequence of the social importance or unimportance of certain school or work-related digital skills is that it reflects, and often amplifies, existing social inequalities.

How to design inclusive virtual learning environments

Based on this analysis, one might wonder how a virtual learning environment could be a meaningful answer to overcoming the variety of barriers that can appear on a learner’s journey. The good news is that this is where design comes in. Let us dive into what can make a virtual learning environment inclusive, bearing in mind some principles to take into account during the process.

Designing a virtual experience that feels natural

Virtual learning environments are not limited to classic e-learning platforms that contain course content and quizzes. They can take forms that would feel more natural to a user who would not be used to digital school practices, as would be the case with a virtual museum. When designing such an environment, the key would be to create the virtual equivalent of a physical space where the user can understand how to move, navigate or look at different elements. In more practical terms, a virtual museum can be built from the immersive experience components of a video game, in particular:

- Giving a sense of agency to the user by allowing them to decide what to do,
- To provide enough space and time for the user to observe the elements at their own pace,
- To create a user-friendly visual identity,
- And, if relevant, to include sound and/or music.

Designing a learning space that is neither an eLearning platform nor a video game

However, a virtual museum or environment is neither an eLearning platform nor a video game, and not even something in between. The goal is for the user to be able to learn and to explore concept, without including tests, as in an eLearning platform, nor challenges, as a video game would. The advantage of not including any form or evaluation makes the experience more accessible to any learner who do not master the codes of formal education (Vodoz, 2010).

Additionally, a virtual museum does not have to hide its goal behind the false pretense of offering a “fun” learning experience like many serious games do, which is actually a strength, in the sense that badly conceived serious games that end up being too serious are generally not as engaging to the learner as they could be (Mons et al., 2020).

Finally, a research report by CNESCO (France's National Center for the Study of School) on the integration of digital tools and practices in France's school system identified the ability to "Present information, represent what was not known/could not be represented before represent before, enrich the information" as one of the pedagogical functions in which the use of digital tools had the most positive impact (Tricot and Chesne, 2020).

Making a museum accessible from anywhere to anyone

Students visit real museums to encourage them to discover new things and "speak" or interact with the subject studied. In addition, by taking a student out of the strict codes of the classroom, they can feel less pressured and more eager to discover things on their own, even on topics they would not feel comfortable tackling on their own. Virtual museum or learning environments can offer similar access opportunities, and reduce access issues to physical museums (distance, mobility, etc.).

However, one need that is true when bringing students to physical museums that carries on to virtual museums is that merely making museum content available online does not make it an inclusive experience. There is a need for guidance, which can be easily provided anytime in the case of a virtual museum, by offering descriptions of the elements exhibited or providing further resources for the learner to explore.

Miraikan: Photo by Ryo Tanaka on Unsplash

At Miraikan, Japan’s National Museum of emerging science and innovation, visitors can walk all around the earth and take a more active role in the exhibition.

Virtual museum inclusive approach for learners with Specific Learning disorders

Specific learning disorders (SLD's) are neurodevelopmental disorders that begin during school-age and have an incidence in the ability to learn with special focus in three areas: writing, reading and math. Other skills may be impacted as well. The most common SLD is dyslexia which is a disorder that concerns reading. SLD's cannot be healed, they can only be managed with the help of experts. According to the American Psychiatry Association (APA): "Learning disorders, if not recognized and managed, can cause problems throughout a person's life beyond having lower academic achievement. These problems include increased risk of greater psychological distress, poorer overall mental health, unemployment/under-employment and dropping out of school".

SLD's may present themselves as a unique disorder or they can be combined, a person with dyslexia may also have dyspraxia for example. According to the APA, one-third of people with SLD's are estimated to have attention-deficit hyperactivity disorder (ADHD). SLD's can occur in different degrees of severity from mild to severe. Finally, these disorders are not correlated to intelligence, people with SLD's often have average and even above average IQ's.

Types of Learning Disorders:

Dyslexia: People with dyslexia have difficulties reading, the difficulties are mainly the association of letters with the sound they make, therefore reading becomes slow and effortful. The reading problems begin even before learning how to read, for instance when trying to break down words into syllables and recognizing the rhythm (APA). In kindergarten, signs of dyslexia begin to appear when children are not able to recognize letters as well as their peers, which often results in avoidance of reading activities from their part in the future.

Dyspraxia: This learning disorder concerns the motor development, people with dyspraxia have difficulties in the acquisition of sensory-motor coordination and visual-spatial functions. In school, it can have an impact on learning geometry, arts and sports.

Dyspraxia can lead to poor organisation skills, slowness, a high level of fatigue for doing the same tasks as the others and difficulties moving around due to spatial organisation challenges.

Dysphasia: Dysphasia impacts the development of oral language, the phonology and decoding the received language. People with dysphasia have difficulties transmitting information because it is hard to understand what they say, causing overall communication difficulties.

Dyscalculia: Dyscalculia affects the capacities of learning numbers and mathematical concepts, understanding symbols and functions. People with dyscalculia have difficulties making sense of numbers, memorizing mathematical concepts and facts, but also general difficulties in problem-solving.

Dysgraphia: Dysgraphia affects spelling, grammar, punctuation, and handwriting. People with dysgraphia have difficulties transcribing their ideas on paper.

Impact of virtual environments in learners with SLD

Virtual environments are beneficial for learners with SLDs because there are less regulations, guidelines, and restrictions in terms of time, setting and schedule.

Individuals with special needs may benefit greatly from virtual environments to learn because of their non-formal environment. It provides interactive learning activities and opportunities for the learner to have control over the learning process. Virtual environments motivate people with SLD's to learn, helping transfer knowledge from the virtual to the real world in a safe learning space (Jeffs, 2009).

Virtual environments allow students an escape from the traditional learning setting and scape the school's constraints, which makes the virtual museum a less stressful environment.

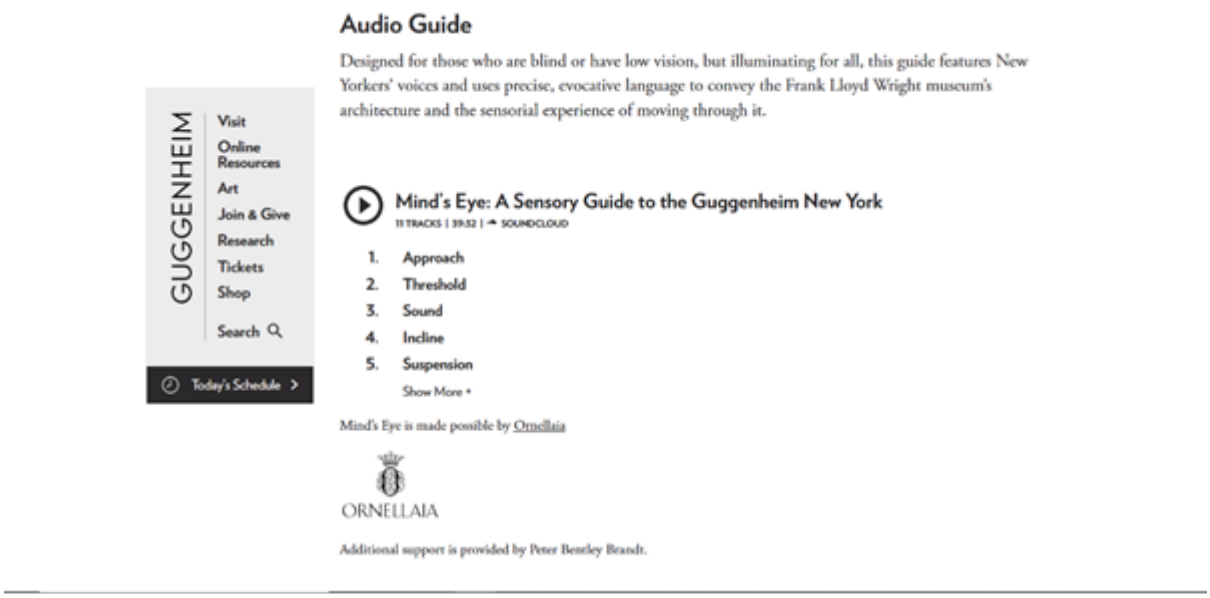
Learning in a virtual environment allow people to learn in an organised framework with structured activities but outside the formal and traditional learning environment.

The formal learning setting can be stressful specially for students with SLD, because they often struggle in school but also because of the restriction of time and the inflexible schedule. This change provides a shift in everyday learning activities that can be beneficial to students in general but specially students with SLD in order to decompress and learn at the same time.

In a virtual museum for instance learners are free to visit any room with different expositions as they please with no time limit. This freedom promotes a flexible and engaging environment for people with SLD that are valuable because as stated previously in some cases they take more time than their peers and they often struggle to stay on track. For this reason, virtual learning environments can be inclusive depending on how they are conceived, not only for people with SLD but also for people with mobility barriers (either physical disabilities or traveling distances).

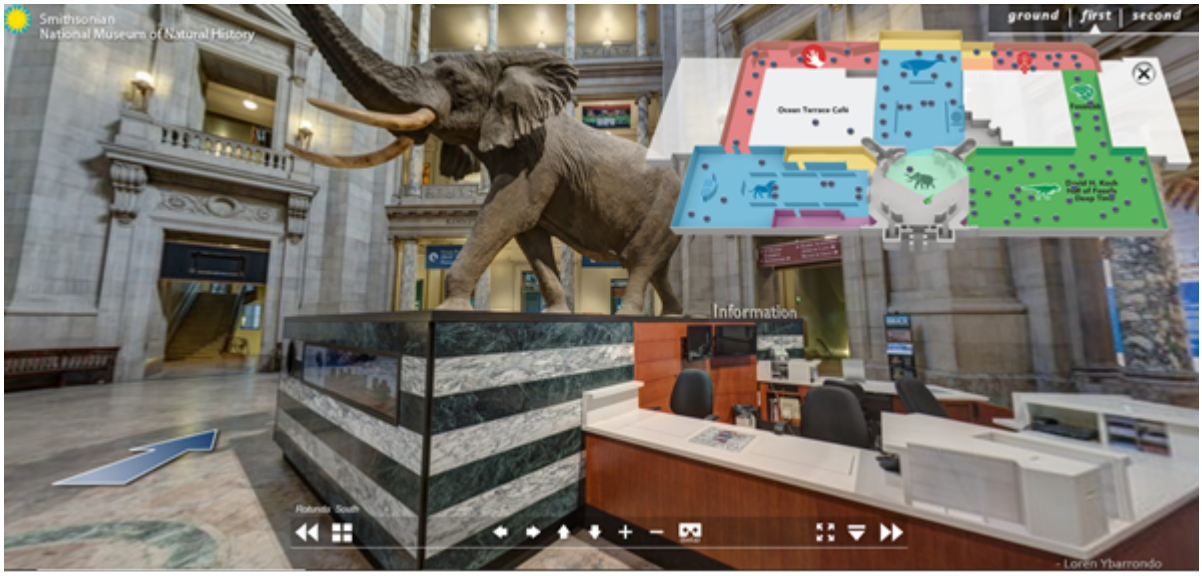
Over time, museums have shown that they play a significant role in education and cultural heritage so the accessibility online of this type of content may be a turning point for motivating and engaging learners that struggle to access it in a physical format. Due to the unlimited amount of time in the virtual environment, learners can carefully examine the exhibits and obtain extra information to enrich the learning process.

Museums can take the inclusion aspect further; for example, the Guggenheim Museum from New York City took inclusion to a new level creating the Mind's Eye: A sensory guide to the Guggenheim New York where they use precise and evocative language to describe the experience of visiting the museum creating a sensorial experience. This guide was created for the blind and visually impaired, but it can also be beneficial for the learners with dyslexia because of the audio guide.



Source: https://www.guggenheim.org/event/event_series/minds-eye

The National Museum of Natural history in Washington D.C. offers an alternative type of experience with a virtual tour in an interactive format that allows the visitor to go around objects and artefacts, zoom in and out with a map on the screen showing where the visitor is at all times in order to facilitate the visit.



Source: https://naturalhistory2.si.edu/vt3/NMNH/z_tour-022.html

To improve accessibility and inclusion a company Tactile Studio specialized in building inclusive virtual museums provide inclusive cultural exchanges through their clients' museums, one of them being the Louvre Museum. The goal of this company is to promote access to arts and culture for everyone designing multisensory educational solutions while being user-friendly as much as possible. It shows that museums are more concerned about being accessible digitally but also, being accessible to all: "Blind and visually impaired, deaf and hard of hearing, people with reduced mobility and people with cognitive impairment. This type of museum accessibility brings physical and psychological comfort for all, and it is crucial in cultural venues" (French architect Nadia Sahmi).

Museums are taking a more human-centred approach considering everybody's needs and making sure that it reflects in the details as accessibility consists in removing present barriers.

Virtual environments for learning can be developed in order to provide different types of activities, such as virtual tours, events, competitions and others. It can be easily shaped to achieve different audiences and provide a wide range of experiences.

Exhibits in virtual museums can be displayed in a panorama mode where the 360 angle, called circular panorama, allows the user to interact with objects. The users can observe the object, zoom in and zoom out and also obtain extra information about them (Atamuratov, 2020). In order to take the best advantage of the virtual environment, exhibits in 3D models are the ones that offer the most benefits concerning the engagement of the virtual museum users because of the realistic results and the pedagogical value of hands-on learning. Exhibits can have different types of materials, for example, pictures, videos, audio recordings and others providing a multisensorial experience that can be accessed anywhere, anytime.

Part 4: Interviews of experts

In the scope of the project, some teachers, educators, or museum workers were interviewed to share their vision about what a virtual museum of STEM should be and what advantages and activities it can provide.

Among these persons was for instance a physics and mathematics teacher, an assistant head in the administrative department of education, culture and sport, a responsible for basic school offers for kindergarten and primary children in a museum, and a museographer (person in charge of defining concepts of exhibitions, and organising the setup and content of the exhibitions).

Expectations and activities of the Virtual Museum of STEM

During the interviews, we asked the respondents what they would expect a virtual museum of STEM would be, what it implies and what functionalities it would have. The responses were diverse, but overall, they see it as a digital place with a lot of multimedia that would immerse the visitors in various interactive activities to learn and discover STEM topics. It would be intuitive, that is to say, easy to follow and use for teachers, trainers and students or any learner. Visitors would have the illusion of being in a real museum in a 3D space with 3D objects which they would be able to interact with. The visitor could also build objects themselves, like reconstituting some elements to learn how it functions. All senses from the learners should be involved during the visit to exhibitions. Some respondents even added that it could include some virtual reality elements. Learners would be allowed to touch, explore, and comment on the exhibitions.

Some participants also proposed that visitors or learners would be represented in the form of avatars, and they could communicate with each other to share knowledge or questions. This way, they can help each other and work together by choice.

According to the respondents, the virtual museum of STEM should have a guide to provide tours to the learners, such as themed tours on a specific topic. There could be temporary exhibitions too, for specific events, for instance, such as the anniversary of an inventor's death. The museum would introduce hands-on experiments to develop the practical skills of the learners. Each theme or element could lead to information research to go deeper into the topic and foster learners' engagement through physical, audio or visual supports. It doesn't have to be too technical, similar to storytelling. It could have extra interactions like "did you know?" or "you may also like" categories to encourage students to go further and to increase their curiosity and engagement.

A museum to integrate into the classroom

Some respondents would also add lesson plans to the museum for language classes, such as grammar or vocabulary related to the exhibition or for theme classes, such as technology. Respondents working in the language sector would also add the CERL levels on each element to guide teachers and educators to use the museum easily according to the level of their students. The virtual museum could, in fact, teach students some new words and lexical fields too.

For the respondents, the museum should include STEAM themes outside the teacher's habits to be used as a complement to the school curriculum and open to other subjects and topics. It would offer experiences or experiments that would be inaccessible, impossible or dangerous in real life, such as a visit to the inside of a volcano. It could introduce some concepts that cannot be done in class also because of the lack of time. Experiments take lots of organisation, from the preparation to the budget and security. It can be hard to set up such an activity during a short lesson. The museum should be a good solution to make students participate in more experiments without all the constraints. However, teachers need to guide students through the museum and all activities, whether they need to do tasks at home or in class. There should be a clear follow-up for each student, even if the visit can be done autonomously. Teachers can let the students discuss what they saw and

explored. They also can let learners choose their own visits. It could improve motivation as students would decide what is more appealing to them. They could choose what theme or collection they want to explore and then do an assignment or just discuss it with the rest of the class.

In terms of inclusion, the virtual museum of STEM should be user-friendly for both dys- learners and ESL (English as a Second Language) students. All students would be allowed to visit the museum for free. Participants also added that the museum must be supported by the Internet and all devices, PC and Apple.

The learning engagement

During the interviews, we also asked the participants what activities they would add to the museum to improve the learners' engagement. According to them, the virtual museum of STEM would be used as an educational plus, as a complement to the lesson. It could be proposed to learners to study before an exam or to introduce a new concept or lesson to the class. Learners could visit the museum on their own and get some autonomy thanks to it. The museum could also be used by students as a support for research assignments, reading comprehension, or even article writing. In conclusion, the Virtual Museum should be used to engage learners actively in the knowledge process and support the learning process, allowing them to observe and express themselves during activities. One participant proposed to work around themes such as "women in STEM", for instance, or learning about potential careers learners could choose in relation to STEM. Another one proposed creating WebQuests, adding a sort of gamification so that students are more motivated to explore the platform and discover elements they wouldn't have checked if they were on their own. Another source of motivation could also be to start any activities or visit a situation that concerns them personally. Overall, respondents talked about activities where students can take action and experiment.

Advantages of the Virtual Museum of STEM

Now that we have the foundations of what should be a Virtual Museum of STEM and what activities it should provide, we can see what the advantages of such a resource can be according to the answers of the participants we interviewed.

The first advantage emphasised by all respondents is the engagement it can provide for the learners. It avoids a lot of restrictions and allows learners to be autonomous and have their own learning process with less judgement and pressure. A virtual museum visit is an experience that cannot happen in a formal environment. No time limit restrains the learners during their experience, and they can freely experiment and explore different outcomes of the different activities. The fear of making mistakes is reduced as they don't have to be supervised and can learn from their own experience online. Each student can visit the museum individually, without distractions from others, which improves focus and productivity. They don't face any restrictions that could exist in ordinary museums.

Moreover, in terms of inclusion, access to the museum is easy, and there are no issues with the proximity, the transportation costs, or the necessary organisation to bring students on such a trip. It allows a better continuity follow-up for each learner for teachers, and it is even available at home for students providing even more convenience and flexibility. As there is one website gathering everything, no time is wasted at the start of the activity, and students cannot spread themselves between too many pages, materials or activities.

Other advantages concerning the museum were highlighted, such as the fact that it allows the development of digital skills, both for the students and the teacher. It uses 21st-century skills and can help students to adapt to these kinds of tools that will be more and more used in the future in educational environments.

The Virtual Museum can be updated and renewed with new elements and collections more frequently than an ordinary museum. Moreover, as collections cannot be modified per the user, the information cannot be changed and is more reliable. It provides curated information.

First impression after testing the Virtual Museum of STEM

Some of the participants had the opportunity to experiment with the first version of the Virtual Museum of STEM we developed in the frame of this project. From their point of view, the museum is a good idea and relatively innovative as it allows to change the learning experience of the learners and increase their engagement. The advantages are numerous, and we have already named them all previously.

However, they suggested that the museum could benefit from greater learner interaction. To achieve this, more tasks and elements could be added, and a guide could be added to provide some guidance and tutorial elements for students. In addition, it could be nice to add the sounds of moving around when the learner is going from one element to another and moves in the museum. Another idea was also to connect the different exhibitions so that there is a common thread linking everything.

Part 5: Best practices

From Belgium

Treasure hunt: In order to make the exploration livelier and more dynamic, you can turn the visit into a treasure hunt by giving your students a list of elements, objects, visuals or words that they need to find throughout the museum and ask them to take note of important information about each element's meaning, origin, context, purpose or usage.

You may create this hunt within a specific exhibition so it can include an element from each collection and subject, or you could make learners work in groups, each one assigned a different exhibition or number of collections, so they can later gather their findings. They could earn points, individually or in groups, based on how many elements they have found and how precise, clear and accurate the additional information is, ensuring that they will pay attention and learn from that playful search. It is necessary to ensure that the competition should remain healthy and respectful and should result in a reward for the most efficient pupil or group.

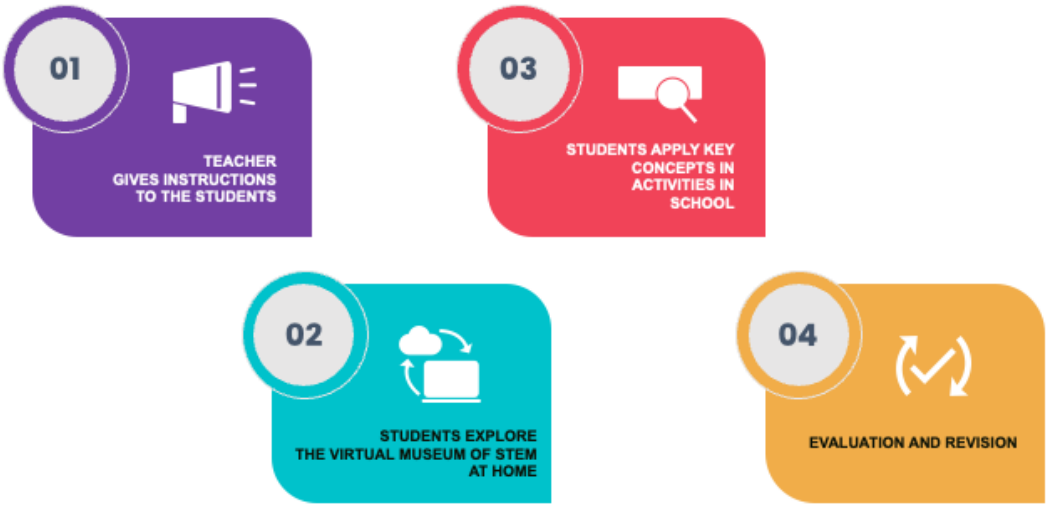
They could also create a presentation or exposé about one or a few elements they'd be assigned in order to share their insight and understanding of each topic with their peers who may not have acknowledged or retained the same information.

From Croatia

How to flip a classroom using the Virtual Museum of STEM :

The virtual STEM museum is certainly an interdisciplinary educational tool that, in addition to enriching the museum experience and the personal experience of visitors, provides new opportunities for teaching and achieving educational outcomes, especially for students with disabilities. One of the modern pedagogical approaches, based on the use of ICT and sharing learning materials is the concept of the flipped classroom, which can be an excellent method for using the Virtual Museum of STEM for independent learning. Flipped classroom goes beyond the traditional classroom, because the teachers should prepare learning materials in advance, for students to be introduced with the materials at home, each at their own pace. In this case, the benefit is that all the materials are already prepared and provided in the Virtual Museum of STEM. The main characteristics of this instructional strategy is to assign new content for homework and through independent learning at home students should make notes and prepare questions for discussion with teacher and students at the next class. When the students come to the next class, besides discussion, the teacher can give them tasks like research, solve problems, make projects of assign them other activities which involve higher order thinking and collaboration with peers. By involving students in those activities, the students are not passive observers, but they are active participants in the teaching process. Based on the student's questions, the teacher can explain the topic additionally for better understanding, but the main role of the teacher is to be a mentor who gives instructions and directs students to their own conclusions.

How to flip a classroom using the Virtual Museum of STEM



From Cyprus

Practical Advice on how to organise field tests and support the students:

- Before conducting the field test, a meeting with teachers was organised to introduce the project goals and demonstrate the Virtual Museum of STEM facilitates the process. During the meeting, teachers will be able to explore the museum and select the topics they wish to incorporate into their lessons. Introducing the museum to teachers before the field tests, allows them to familiarize themselves with it and support their students in the learning process.
- During CIP's field test, the Microcontroller's exhibition was used as an introduction to the technology and robotics lesson, where the students had the hardware in front of them, and they compare it with what they learned in the museum. The students learned about the different components of Arduino, so AE2 was useful for them.
- During the field test:
    - Encourage students to work in groups to explore the museum and complete activities.
    - Assign students a research project that involves exploring the museum and creating a report or presentation based on what they discover.
    - Encourage students to explore the virtual museum and discover new exhibits and topics that interest them.
    - Assist the students when necessary and ask them questions to make sure that they understood the topic they are working on.

From France

Using the collections in the museum as introductions to topics: the example of Augmented Reality

Using a collection can be a great way to introduce a topic before a pratical activity. We did so and presented the collection on Augmented Reality to students to introduce the concept, its history and applications, before diving into a practical activity on integrating Augmented Reality elements through open-source resources software.

Thus, you can use the reusable models from another Erasmus+ project called 'DIMPA' (for 'Digital Innovative Media Publishing for All'. Even though they were created as resources for vocational education and training, the step-by-step approach of the suggested Augmented Reality activities allows any teacher to use them in the classroom. Such activities can be carried out with students aged 10-18: with younger students, it will be necessary to adopt a step-by-step approach and to ensure that everyone is at the same stage before moving on, while older students can be more independent and ask the teacher for support when they need it. In addition, older students might be able to spend more time customising the 3D models, and this activity can be integrated into a coding lesson.

Therefore, if you are interested in any of the museum collections, try to think about ways to couple them with practical activities!

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From Portugal

There are some good practices for setting up the field tests:

1. Clearly state the field test's goals and objectives. It is crucial to know exactly what you want to accomplish.
2. Pick participants from a variety of backgrounds. Students with various ages, backgrounds, and skill levels may be included in this. If you intend to implement the field-test with materials available in English, please make sure the students will be ready to fully understand them.
3. Give crystal-clear directions and advice. To assist students, consider offering a brief tutorial or guide. If necessary, you can adapt the PPT presentation prepared by CEPROF for the Portuguese field tests.
4. Keep an eye on students' progress and offer assistance as required. This may entail responding to queries, resolving technical problems, and offering instructions.
5. After the field test is complete, be sure to collect feedback from students and evaluate the results. Consider what worked well and what could be improved, and use this information to make changes and adjustments as needed.

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Co-funded by the Erasmus+ Programme of the European Union

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project number: 2020-1-FR01-KA226-SCH-095602