



Teacher education is a deeply pedagogical process rooted in values, ethics, and the social purpose of schooling. Globally, it sits at the core of educational quality and fairness, as research in comparative and international education demonstrates: the training of teachers directly influences students' learning chances, social inclusion, and the democratic aims of schools. Teachers are not simply transmitters of curricula, but active professionals whose convictions, reflective skills, and ability to manage the complexities of classroom life give shape and substance to the educational experience itself.

The pedagogical dimension of teacher education frames teaching as a relational, context-aware, and ethically grounded profession rather than just a set of procedural skills. From a research perspective, this demands robust research methodologies that can critically examine the complex realities of schools and inform evidence-based policies. Equally important is the connection between theory and practice, which helps to bridge the persistent gap between universities and schools.

The contributions gathered in this volume reflect the richness and diversity of experiences showcased during the ATEE Spring Conference 2024, held at the University of Bergamo from May 29 to June 1, 2024. The volume presents 70 selected papers out of more than 300 presented by researchers representing over 40 countries.

This broad spectrum of studies highlights promising directions that can inspire renewed inquiry and concrete proposals aimed at improving contemporary educational systems.

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Teacher education research in Europe: trends, challenges, practices and perspectives

May 29th – June 1st, 2024
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Edited by Nicole Bianquin and Francesco Magni





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BOOK OF PROCEEDINGS

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Digital Innovation and Artificial Intelligence in Museum Education: perspectives, debates and psychological implications

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Abstract

This paper investigates the impact of digital innovation and artificial intelligence (AI) on museum education, focusing on the transition between the real and virtual world and the involvement of all educational actors, including schools, teachers and students. Through an analysis of case studies, recent debates and concrete experiences, the integration of virtual reality (VR) and AI in museum contexts is explored. The methodology is based on the analysis - through studies and field experiences - of the educational perspectives offered by these technologies, with a focus on the psychological effects related to motivation, information retention and the development of key skills. The research investigates how VR and AI can overcome physical barriers and personalise learning, balancing technological innovation and human elements to maximise educational effectiveness.

Keywords: museum education; virtual reality; artificial intelligence; digital innovation; school.

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¹ For the purposes of scientific recognition, please note that the introduction and paragraph 1 are attributed to Valentina Berardinetti, paragraph 2 to Michele Ciletti, paragraphs 3 and 4 to Andreana Lavanga, the abstract and conclusions to Giusi Antonia Toto.

1. Introduction

The integration of digital innovation and artificial intelligence in museum education represents one of the most promising and debated frontiers of the contemporary educational landscape. These tools, capable of redefining the ways of learning and interacting with cultural heritage, offer extraordinary opportunities to make museums inclusive, interactive and personalised spaces capable of meeting the needs of an increasingly diverse and technologically advanced society.

Today, also in the light of the educational alliance between schools and the surrounding area, the museum is much more than just a place for the preservation of cultural heritage: alongside its transmissive or instructive role, where knowledge is offered in a structured and direct way, often through the guidance of experts or cultural mediators, the museum is increasingly becoming an educational space, where knowledge is constructed through active interaction between visitors, content and context. In this sense, the museum balances the need to be a place of active learning with the importance of providing solid and well-contextualised knowledge in order to ensure the understanding of complex concepts or to preserve the authority of certain contents.

Unlike other traditional educational spaces, such as schools or universities, the museum offers a unique environment in which learning takes place through direct experience, reflection and personal discovery in line with the constructivist principles of Piaget and Vygotskij (Calvani, 1998; Giaconi, 2008). Here, the visitor is not just a passive recipient of information, but an active protagonist who interprets, reworks and connects knowledge to his or her own experience. This educational dimension is expressed in different ways: narrative paths that stimulate the imagination, interactive tools that engage the senses and innovative technologies that make learning accessible, participatory and personalised.

Indeed, the museum as an educational space is not limited to the transmission of content, but fosters the development of critical and creative skills. The enjoyment of works of art, historical objects or scientific content becomes an opportunity to explore cultural connections, reflect on universal issues and cultivate independent thinking. In this sense, the museum not only enriches the visitor cognitively, but also contributes to his or her personal and emotional growth.

The introduction of digital tools and artificial intelligence further amplifies the museum's educational potential, transforming it into an increasingly dynamic, inclusive and interactive environment. Technologies such as augmented reality, virtual tours or artificial intelligence-based assistants can create tailor-made experiences for visitors, adapting to their interests, knowledge level and learning style. These innovations not only broaden access to cultural heritage, but also enrich the educational experience by making it more engaging and immersive.

However, the adoption of these technologies also poses significant challenges. It is crucial to avoid that interaction with digital tools reduces the authenticity of the museum experience or that the use of artificial intelligence limits the critical thinking of visitors, turning them into mere consumers of pre-packaged content. On the contrary, the museum must know how to integrate technologies in a conscious way, using them as tools to enhance learning, stimulate curiosity and encourage critical reflection on the content on offer.

This study, therefore, investigates - also through the analysis of concrete experiences - the museum as an educational space and an irreplaceable resource for contemporary society, a place where tradition and innovation meet to promote knowledge that is not only informative, but transformative. Through the challenges and opportunities offered by today's digitised society, the role of artificial intelligence and digital technologies in museum didactics is explored, and it is proposed to reflect on how these tools can enhance the museum as a learning laboratory, where each visitor finds the opportunity to grow, discover and connect with cultural heritage in an authentic and meaningful way.

2. Evolution in Museum Education: new opportunities and challenges

In recent decades, museum education has undergone a profound transformation, moving from a traditional approach, focused on the mere display of objects, to a dynamic and interactive paradigm

that enhances the visitor experience. This evolution has been driven by a growing awareness of the educational and social role of museums, as well as by technological innovations that have broadened the possibilities of enjoyment and participation. Initially, museum education was reserved for an elitist audience, focusing on the preservation and dissemination of historical and artistic collections. However, with time and the advent of the new museology in the 1970s–1980s, there was a significant shift towards an interdisciplinary approach that put the visitor and his or her interaction with cultural heritage at the centre. This approach encouraged museums to transform themselves into spaces for dialogue, learning and inclusion, offering new and multiple opportunities especially to the school world (Toto, 2024).

Museums have started using participatory approaches that actively involve visitors through workshops, interactive events and customised educational programmes, making the museum experience more accessible and meaningful. The digitisation of collections has opened the door to a global audience, overcoming geographical and physical boundaries and offering high quality educational resources available everywhere. Among the most significant innovations, the use of immersive technologies such as virtual reality (VR) and augmented reality (AR) has revolutionised the museum experience (Rossi et al., 2024). Virtual reality allows visitors to fully immerse themselves in reconstructed three-dimensional environments, offering unique and detailed sensory experiences ranging from visiting archaeological sites such as the ruins of ancient cities to exploring the depths of the oceans or travelling through space, as exemplified by the experiences available in astronomical observatories or science museums, such as the 'Leonardo da Vinci' National Science and Technology Museum in Milan². This technology transcends physical limits, providing access to inaccessible collections or remote locations, and is a powerful educational tool for deepening historical and cultural understanding. Augmented reality, on the other hand, enriches the real experience through digital overlays, providing additional information on works and exhibits or animated reconstructions showing their original use or historical context. For example, visitors can point their mobile devices at a painting to view hidden layers, such as sketches or modifications, or watch a statue 'come to life' and tell its story, as can be experienced in the visit to Casa Batllò, during which at the end of a virtual tour that allows visitors to reconstruct the history of the place, it is possible to enjoy a 360-degree immersive experience that allows the visitor to better understand the genius of Gaudí's art³.

These technologies not only improve accessibility and audience engagement, but also contribute to personalised teaching, adapting to the learning needs of different types of visitors. In school contexts, VR and AR are proving to be extremely effective tools to complement the traditional curriculum. Through simulations and interactive environments, students can delve into complex concepts in an engaging way, improving comprehension and memory. For example, a virtual journey to ancient Egypt can complement history lessons, while augmented analysis of artworks allows for the exploration of pictorial techniques and symbolic meanings, enriching art history teaching.

Interdisciplinary collaborations between museums, schools, universities, research centres and artists are a further strength for museum education, as they foster the creation of innovative content that integrates history, art, science and technology, thus expanding learning opportunities. Particularly relevant is the integration of museum education into school curricula. Guided tours and educational workshops offered by museums are complementary experiences to the traditional curriculum, enriching students' education through direct contact with cultural and historical heritage, which also helps them to regain their identity and get in touch with their origins. Collaboration between schools and museums enables the development of interdisciplinary projects that stimulate critical thinking, creativity and experiential learning (Re, 2023). For example, many schools organise thematic tours involving different disciplines, such as art history, science and literature, using museum resources to explore complex topics in depth and link them to real-life contexts. In addition, museum education in schools contributes to developing cultural awareness in young people, promoting values such as respect for diversity and common heritage. This integration also has a significant impact on social inclusion, offering students from disadvantaged backgrounds the opportunity to access high quality educational experiences (Lora, 2020).

² For further information visit the website: <https://www.museoscienza.org/it/offerta/virtual-zone>.

³ For further information visit the website: <https://www.casabatllo.es/it/experience>.

Despite this progress, significant challenges remain. The cultural and social diversity of visitors is often underrepresented, and many museums face the task of reformulating their narratives to include more diverse perspectives accessible to all. Economic sustainability is another critical issue, as the implementation of advanced technologies requires considerable financial resources and specialised technical skills on the part of teachers and museum staff (Castillo et al., 2023). Training of museum staff is crucial to meet these challenges, ensuring that educators are prepared to use digital tools, design interactive experiences and manage the dynamics of heterogeneous groups (Orlandi et al., 2023). Moreover, museums need to strike a balance between respecting tradition and introducing innovations, ensuring that new technologies do not compromise the historical and cultural integrity of collections.

A key element for the future of museum education is the continuous evaluation of programmes by collecting feedback from visitors and analysing the educational impact of proposed activities. Tools such as questionnaires, interviews and digital data analysis can provide valuable information to optimise the offer and better respond to the needs of the public. One of the most fascinating transformations in museum education is the adoption of multisensory narratives. More and more museums are integrating experiences that involve not only sight, but also hearing, touch and even smell, creating a deeper and more immersive interaction. The use of tools such as narrative audio guides, tactile panels for the blind and sound reconstructions of historical environments enriches the understanding of cultural heritage, making the experience inclusive for different categories of visitors. An important experience in this sense is that of the Civic Museum of Accadia, in the inland areas of the Monti Dauni, which with its new multimedia set-up in no less than 11 rooms - including gaming stations, sliding monitors, touch screens, artwalls, lightboxes, videos and video projections, digital avatars, drone footage and sensor technologies - narrates the archaeology, history and territory of Accadia, promoting the Fossi district and exploring every natural, historical and human facet of the municipal territory⁴.

Ecological sustainability has emerged as another crucial challenge. Many museums are investing in green technologies and environmentally sustainable practices to reduce the environmental impact of their activities. From the reduction of energy consumption to the use of recycled materials for exhibitions, these efforts demonstrate how the museum sector can actively contribute to environmental protection while strengthening its educational role. Contemporary museums are also places of social experimentation, where complex issues such as the inclusion of marginalised communities, the representation of cultural identities and collective memory are addressed. Exhibitions co-created with local communities or minority groups are an effective model for promoting intercultural dialogue and stimulating critical reflection.

The ability to adapt quickly to change has emerged as a determining factor, especially in light of recent global challenges such as the COVID-19 pandemic. During this period, many museums developed virtual and interactive content to maintain audience engagement, demonstrating remarkable resilience. However, the digital transition has also highlighted inequalities in access to technology, highlighting the need for policies aimed at bridging the digital divide. Museum education, therefore, is in a moment of great transformation, where alongside the challenges to be faced and overcome, related to equity and education, the potential and opportunities offered by immersive technologies and participatory technological approaches are enormous.

3. The confluence of Virtual Reality, Artificial Intelligence and museum education: state of the art and future implications

From a strictly technological perspective, we are witnessing increasingly substantial investments, both in terms of time and financial resources, in the development of Generative Artificial Intelligence systems, particularly those based on Large Language Models (LLMs). Since October 2022, when OpenAI released ChatGPT 3.5, a chatbot capable of generating coherent and contextually relevant text, the field of AI has experienced exponential growth. The potential of these models, further refined

⁴ For further information visit the website: <https://ettsolutions.com/progetti/moa-museo-origini-accadia>.

in subsequent versions like GPT-4, lies in their ability to understand and process natural language, enabling advanced applications such as automatic text generation, real-time translation, and the creation of increasingly sophisticated conversational agents. The impact of LLMs on museum education could be significant: for instance, it could allow the creation of virtual guides capable of interacting with visitors in a natural and personalized way, answering their questions, and providing in-depth information on the exhibited works (Pietroni, 2019).

The potential of Artificial Intelligence, however, extends far beyond mere text generation. Novel transformer-based and diffusion-based models have achieved unprecedented results in converting text to images and, more recently, to video. Their architecture, based on neural networks capable of learning complex patterns from large datasets, allows for the creation of highly realistic and detailed visual content. Examples include DALL-E 2 and Imagen 3 for image generation, and Sora and Runway Gen-3 for video generation. Even more transformative is the recently announced Google model Genie 2, that is reported to be capable of generating entire explorable, virtual worlds from simple text prompts (Holder et al., 2024). These technologies could revolutionize the way museum content is created, enabling the generation of customized visual experiences based on the interests and preferences of individual visitors.

There exists significant potential in the possibility of interconnecting various Artificial Intelligence technologies and in linking them with other cutting-edge technologies, such as Virtual Reality (VR). Defined as a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors (Burdea et al., 1996), VR offers an unparalleled level of immersion and engagement. The integration of AI, particularly Generative AI, with VR can enhance the realism, interactivity, and personalization of virtual experiences (Suh & Prophet, 2018).

It is evident how the mass generation of realistic, high-quality, and highly customized videos can be leveraged in the VR domain. Potential applications include the creation of virtual environments that dynamically adapt to user interactions, the generation of virtual characters capable of natural and believable interactions, and the creation of personalized educational experiences based on the user's learning style and interests. The combination of VR and AI can, therefore, transform museums into even more dynamic and interactive learning spaces, offering visitors a unique and engaging way to interact with cultural heritage (Bekele et al., 2018).

Museum education represents one of the fields where VR has already found flourishing applications for several years: the possibility to immersively view and virtually interact with artifacts, distant historical realities, and reconstructed scenarios effectively lends itself to such technology. For instance, the British Museum has used VR to allow visitors to experience a Bronze Age roundhouse, while the Louvre Museum has partnered with HTC Vive Arts to offer a VR experience that lets users interact with the Mona Lisa (Puig et al., 2020).

In this context, it becomes apparent how Artificial Intelligence can elevate this entire paradigm to an even more advanced level. AI could analyze user behavior within the virtual environment to adapt the experience in real-time, offering content and interactions tailored to individual preferences. For example, AI-powered virtual assistants could guide visitors through a virtual museum, providing detailed information about the exhibits and answering questions in real-time (Duguleană et al., 2020). Imagine a virtual tour of an ancient Roman city, where an AI-powered virtual guide accompanies the visitor, explaining the history and significance of the various buildings, and adapting the narration based on the visitor's interests and questions. Such an experience would not only be highly engaging but also profoundly educational. As Bekele et al. (2018) suggest, the integration of AR, VR, and Mixed Reality (MR) can greatly enhance the preservation and interpretation of cultural heritage by offering new avenues for education and engagement.

Naturally, certain practical considerations still constrain the development and widespread adoption of such systems. These include the high computational cost of generating high-quality videos, the need for large datasets to train AI models, and ethical considerations related to the use of personal data for experience customization. Furthermore, issues of accessibility and digital divide must be addressed to ensure that these technologies can benefit all potential users, regardless of their socio-economic background or technological literacy (Shehade & Stylianou-Lambert, 2020).

To fully harness the potential of the convergence of VR and AI, future research should focus on exploring the long-term impact of these technologies on learning outcomes and visitor engagement, as well as developing best practices for their ethical and inclusive implementation in diverse museum settings. It is hoped that ongoing research and development efforts, combined with a focus on ethical considerations and accessibility, will pave the way for a new era of museum education, where technology and human creativity work hand in hand to create enriching and transformative experiences.

4. Digital Innovation and Artificial Intelligence in Museum Education

Museum education serves as a privileged domain for fostering motivation, creativity, and skill development among visitors, particularly students. Through interactive and immersive experiences, museums facilitate active learning that engages emotions and curiosity—essential components of the educational process. Direct and personal engagement with artworks, historical artifacts, and reconstructed environments provides a multidimensional approach to knowledge, stimulating critical thinking and reflection. This mode of interaction enriches participants' cultural heritage while promoting the development of transferable skills such as problem-solving, collaboration, and effective communication. Furthermore, creativity is significantly enhanced through the application of innovative technologies like augmented reality (AR) and virtual reality (VR), which allow for unique reinterpretations of cultural heritage. Consequently, museum education transcends mere knowledge transmission, functioning as a catalyst for holistic and inclusive learning, preparing individuals to confront the challenges of the contemporary world (Sani & Trombini, 2003).

Numerous empirical studies validate the efficacy of museum education in promoting motivation, creativity, and skill acquisition. For instance, Falk and Dierking (2016) demonstrated that museum experiences can enhance students' interest and motivation toward academic subjects, illustrating how informal learning in museums often proves more engaging than traditional classroom instruction. Similarly, Hooper-Greenhill (2000) explored the impact of interactive activities, revealing that visitors involved in hands-on workshops develop greater critical and creative thinking abilities. Kisiel (2014) examined the ways in which school visits to museums can bolster transferable skills such as teamwork and communication, showing significant improvements in students' collaborative and presentation capabilities. Packer and Ballantyne (2002) found that museum experiences, particularly when integrated with guided tours and workshops, positively influence long-term learning, fostering a deeper understanding of the subjects addressed.

5. Virtual Reality and Psychological Implications of Museum Education

Recent advancements in technology and the proliferation of artificial intelligence (AI) have transformed the museum landscape, significantly impacting educational and creative processes. The integration of interactive systems, digital games, augmented reality, and virtual reality has revolutionized the visitor experience, creating more engaging and personalized learning environments (Ovallos-Gazabon et al., 2020). Gamification and interactive experiences enhance intrinsic motivation, stimulating curiosity and interest in exhibited content, while AI facilitates the adaptation of educational activities to individual needs, thereby improving emotional connections with cultural heritage (Coppola & Zanazzi, 2020). Such personalized experiences facilitate the assimilation and retention of information, rendering learning more meaningful.

Moreover, modern museum education encourages exploration and discovery, which are crucial for cognitive development. Through interactive environments, visitors can exercise critical thinking and creativity while addressing complex problems in real-world contexts. However, the introduction of digital technologies and AI presents challenges, including the need for training museum staff and managing ethical considerations related to transparency and bias in AI-driven decision-making

processes (Castillo et al., 2023). Despite these challenges, technological innovation offers remarkable opportunities to transform museums into dynamic centers of learning and personal growth.

The integration of gamification within educational frameworks, both in school and museum contexts, represents an effective strategy for enhancing engagement and facilitating learning. By leveraging playful elements, the educational experience can be transformed into an active and engaging process, wherein students and visitors are not merely passive recipients but active participants. This methodology stimulates curiosity and discovery, promoting collaborative learning that fosters the exchange of ideas and the construction of shared knowledge. In particular, in museums, the application of games and interactive activities not only enhances content accessibility but also cultivates an inclusive environment in which each participant can explore and deepen their understanding at their own pace. Thus, gamification emerges as a potent tool for modernizing educational experiences, addressing the needs of an increasingly digital and interactive society (Ragni et al., 2023).

In particular, virtual reality (VR) has demonstrated a significant impact on the emotional and cognitive experiences of visitors. A study conducted in 2011 investigated how gamification can influence engagement and learning outcomes among students. The authors provided empirical evidence demonstrating that gaming techniques can effectively enhance student motivation, making learning more engaging and interactive (Lee & Hammer, 2011). Another noteworthy study by Hamari et al. (2014) conducted a meta-analysis that aggregated data from various previous studies, highlighting a positive impact of gamification on learning outcomes. The results point to mostly positive results, for instance, in terms of increased motivation and engagement in learning activities as well as enjoyment of them, providing valuable insights for educators and instructional designers. However, at the same time, studies have indicated negative results to which attention needs to be paid, such as the effects of increased competition, difficulties in evaluating activities and design features. These studies offer a clear and compelling overview of the effectiveness of gamification in both educational and museum contexts, underscoring how VR not only enriches the educational experience but also fosters meaningful connections between visitors and cultural heritage.

6. Conclusions

The museum today therefore emerges as an interdisciplinary laboratory, where past, present and future intertwine to generate transformative educational experiences. The possibility of combining advanced technological approaches with participatory and inclusive methodologies represents an unprecedented opportunity to democratise access to cultural heritage. This model, however, requires a solid collaborative research infrastructure involving experts in cognitive science, educational technology, cultural psychology and museum studies.

For such innovations to have a significant impact, it is essential to develop a theoretical and methodological framework to guide the integration of immersive technologies in museum contexts. This framework should include the systematic evaluation of the effects of virtual experiences on different user groups, with particular attention to the dimensions of cultural diversity, cognitive abilities, and accessibility conditions.

Thus, the convergence of museum education and immersive technologies represents a promising frontier for cultural and science education, but requires an evidence-based approach, interdisciplinary collaboration and constant monitoring of long-term effects. Only through a conscious and critical integration of these tools will it be possible to realise museums capable of educating, inspiring and transforming, contributing to a more inclusive society aware of its cultural heritage.

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