

Research article

The push for artificial intelligence in education. Innovations in museums

El impulso de la inteligencia artificial en la educación. Innovaciones en los museos

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Receipt Date: 12/09/2025

Acceptance Date: 14/10/2025

Publication Date: 19/10/2025

How to cite the article

Fernández Jiménez, A., & Fernández-Hernández, R. (2025). The push for artificial intelligence in education. Innovations in museums [El impulso de la inteligencia artificial en la educación. Innovaciones en los museos]. *European Public & Social Innovation Review*, 10, 01-21. <https://doi.org/10.31637/epsir-2025-3123>

Abstract

Introduction: Artificial Intelligence (AI) is set to revolutionise the museum experience across the board. Museums will benefit from AI's ability to analyse visitor data, deliver personalised educational content, manage the institution and preserve heritage. **Methodology:** This analysis uses a systematic literature review, using the PRISMA protocol, of recent studies and literature to elucidate the applications of AI in museum settings. **Results:** AI enhances museum activities, exhibitions, and educational practices by providing personalised and adaptive experiences. **Discussion:** While the transformative potential of AI is evident, challenges remain, such as ensuring authenticity, security of digital representations, protection from environmental hazards, unauthorised access, and ethics. **Conclusions:** AI has immense potential to enhance visitor engagement, digital preservation, and educational outreach in museums. Despite the challenges, the evolving technology offers promising avenues for improving museum experiences and educational outcomes. Further research and collaboration are essential to maximise the benefits of AI while addressing these challenges.

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Keywords: diverse learners; adaptive learning; chatbots; personalized educational content; educational outreach; museum experiences; Artificial Intelligence (AI); visitor engagement.

Resumen

Introducción: La inteligencia artificial (IA) está llamada a revolucionar las experiencias de los museos en todos sus ámbitos. Los museos se benefician de la capacidad de la IA para analizar los datos de los visitantes, ofrecer contenidos educativos personalizados, gestionar la institución y mantener el patrimonio. **Metodología:** Este análisis emplea una revisión bibliográfica sistemática mediante el protocolo PRISMA de estudios y literatura recientes para dilucidar las aplicaciones de la IA en entornos museísticos. **Resultados:** La IA mejora las actividades del museo, las exposiciones y prácticas educativas ofreciendo experiencias personalizadas y adaptativas. **Discusiones:** Si bien el potencial transformador de la IA es evidente, siguen existiendo desafíos como garantizar la autenticidad, la seguridad de las representaciones digitales, la protección contra los riesgos ambientales, el acceso no autorizado y la ética. **Conclusiones:** La IA tiene un inmenso potencial para mejorar la participación de los visitantes, la preservación digital y la divulgación educativa en los museos. A pesar de los desafíos, la evolución de la tecnología ofrece vías prometedoras para mejorar las experiencias de los museos y los resultados educativos. Es esencial seguir investigando y colaborando para maximizar los beneficios de la IA y, al mismo tiempo, abordar estos desafíos.

Palabras clave: alumnos diversos; aprendizaje adaptativo; chatbots; contenidos educativos personalizados; divulgación educativa; experiencias museísticas; Inteligencia Artificial (IA); participación de los visitantes.

1. Introduction

In the tourism industry, cultural heritage is considered a product with great potential as a commercial attraction (Kabassi, 2019). Museums are the places that house a large part of this heritage, in addition to being institutions that are highly valued socially, which leads them to have a greater number of visitors each year who want to live experiences and obtain social benefits (Kotler, 2001). Initially, museums focused on their core activities of collections, research and exhibitions. With time and changes in consumer demand, they have adapted to a new paradigm (Anderson, 2004), which has meant that museums have become more accessible and democratic, with the aim of attracting more visitors by improving their experience (Anderson, 2004).

With the development of new technologies and the digitalised society, there have been changes in the way audiences relate to each other and to companies and institutions. The Internet has created a wide range of communication tools that facilitate interaction and relationship building between organisations and their audiences through interactive and collaborative resources and platforms (Cuomo *et al.*, 2021). Tools such as websites, social networks, blogs, forums, mobile applications, virtual communities, and especially the combination of several of them, contribute to improving the commercial strategies of museums (Fernandez-Lores *et al.*, 2022). They also turn visitors into content generators, influencing future visitors through their comments and evaluations, as in the case of virtual communication (Fernandez-Hernandez *et al.*, 2020).

The inclusion of AI in the museum space can lead to greater access to cultural heritage through increased content on the web, through advanced search or scanning tools. This can give greater value to museums as an educational resource for both physical and web visitors. Artificial intelligence (AI) can transform visitor experiences in museums, offering personalized tours, interactive exhibits, and state-of-the-art archiving systems.

Museums will benefit from AI's ability to analyse visitor data and deliver personalized educational material. As mentioned above, AI can be very beneficial for museums, but are museums ready to incorporate AI into their daily lives? Are there already experiences of museums using AI? This research aims to answer these questions through a systematic literature review, which will serve as a basis for future research in this area.

2. Literature review

2.1. Artificial Intelligence (AI) in museums

The democratisation of technology has allowed the knowledge of Artificial Intelligence (AI) to spread to various industries, including the cultural industry, and more specifically to museums. This knowledge has made it possible to understand the possibilities that AI offers museums in different areas:

2.1.1. In the internal management of museums

AI can improve museum security by monitoring the movement of people to detect and alert staff to suspicious behaviour or potential threats within the museum. It can also help the institution's staff keep track of inventory and manage collections more efficiently. It can also help optimise resource and budget allocation. It can also help manage visitor flow by providing real-time analytics and suggestions to optimise visitor flow. AI algorithms can help museum staff anticipate visitors' needs in terms of common questions they may ask (Centorrino *et al.*, 2021).

Importantly for museum curators, AI can help monitor and control weather conditions to preserve works of art. Finally, it can help preserve, digitise and catalogue works of art, making them accessible to a global audience (Tong & Ma, 2021). Another area where AI can make a positive contribution is in streamlining ticketing and booking processes, reducing waiting times and making the visitor experience more enjoyable. This is in addition to streamlining other operational processes such as scheduling, staffing and budget allocation to ensure efficient museum management (Wang *et al.*, 2023).

AI can analyse visitor demographics to tailor marketing and outreach efforts. It can also help recommend tailored content, activities and educational programmes for specific audience segments, increasing visitor participation and engagement (Wu, 2017). It can also help translate signage and exhibit communications into multiple languages, making museums more welcoming and accommodating to international visitors. One of the problems museums faces is preserving works of art and preventing them from being damaged during transport or exhibition; AI can create replicas that can be taken anywhere in the world, preserving the original for future generations.

2.1.2. In the exhibits and visitor experience

AI can analyse visitor traffic patterns and optimise museum designs to improve visitor flow and accessibility, enhancing the sustainability of the museum space. In exhibitions, AI can enhance the visitor experience by personalising tours, exhibition design, activities, museum content and recommendations based on individual interests and preferences, which can be learned through their feedback and behaviour. It can also provide real-time translations for foreign visitors, making the museum more accessible to a wider audience. It can also provide audio descriptions and subtitles for visually impaired visitors, making exhibits more accessible to a wider range of people (Centorrino *et al.*, 2021).

AI can generate personalised recommendations for further exploration of the museum's collection based on visitors' interactions and preferences. It can also provide interactive tour guides that provide additional information and context for exhibits. It can analyse visitor behaviour to identify patterns and trends in engagement, enabling museums to optimise their exhibits and programmes to enhance the visitor experience. This analysis also allows them to optimise the placement and layout of exhibits, creating a more engaging and intuitive museum design.

2.1.3. Digital environment in the museum

Artificial intelligence has also been used in museums to develop virtual reality exhibits that transport visitors to different periods of history, allowing them to explore and learn in a unique way. It has helped create interactive exhibits that respond to visitors' gestures, facial expressions and voice commands, creating a more immersive and interactive experience for visitors. It also analyses their participation in such exhibits to improve future exhibit designs and the overall visitor experience (Wang *et al.*, 2023). The incorporation of augmented reality offers innovative ways for visitors to interact with exhibits (Garcia-Pereira *et al.*, 2020).

By combining different technologies, such as interactive multimedia experiences with augmented reality overlays, exhibitions can be brought to life. In addition, AI-powered virtual assistants can provide diverse and engaging interactive and information experiences. Natural language processing can be used to create interactive chatbots that can answer visitors' questions and provide real-time information. To prevent repeat visitors from falling into a routine and seeing what they already know, AI can use facial recognition technology to personalise the visitor experience by identifying repeat visitors and providing recommendations or alternative tours based on previous interactions with the museum (Tong, & Ma, 2021)

Using AI on the museum's website can streamline visitor navigation through interactive maps and wayfinding features, enhancing the visitor experience. It can also personalise the content displayed on both the web and social media to match the interests and preferences of your audience and analyse social media data to understand sentiment and preferences, allowing museums to tailor their marketing strategies and offerings. Users leave a lot of information on the internet that can be very useful for decision-making, and AI can collect and analyse visitor feedback in real time to improve curation and exhibition design, contributing to the satisfaction of the museum experience (Giannini & Bowen, 2022).

Since the last century, museums have sought to democratise culture by making their facilities accessible to as many people as possible (Bonet & Négrier 2019). Not all museums are accessible, due to their physical location and the barriers they may present to people with disabilities. Therefore, this full democratisation can be achieved through new technologies (Fernández-Hernández *et al.*, 2020) and, more specifically, through AI, through virtual tours adapted to this public or through audio descriptions or sign language interpretation for in-person visits.

2.1.4. *In the field of education*

The use of artificial intelligence in education is transforming the way students learn and engage with their environment. By providing personalised learning experiences, adaptive environments and intelligent tutoring systems, AI has been shown to significantly increase student engagement and improve learning outcomes across a range of subjects (Chen *et al.*, 2020; Brown *et al.*, 2018; Holmes *et al.*, 2019). This shift in education offers great potential for the future of learning (Fernández, 2022).

The impact of AI on education is significant. AI has the potential to personalise learning for each student by providing personalised instruction and support. Educators can use AI to monitor student progress and provide targeted interventions as needed, leading to a more personalised and effective learning experience. In addition, AI can help bridge the gap in access to quality education by providing resources and support to students in underserved communities.

As AI continues to advance, its potential to transform education and improve student outcomes is truly remarkable. The possibilities are endless and the impact on education is profound (Holmes *et al.*, 2019). AI can enhance educational programmes by creating personalised learning experiences for visitors of all ages and backgrounds, tailored to individual learning styles and interests. AI can create interactive games or quizzes for visitors to enhance their understanding of the museum's collection (EVE, 2023). AI can adjust the level of difficulty or content based on user interaction. This creates a more personalised experience for everyone (Wu, 2017).

2.2. *The importance of artificial intelligence for the museum experience*

Museums and visitors have long been able to interact. This interaction can enrich the visitor's overall experience, encourage deep reflection on the exhibits, and gradually deepen their personal interests. It can also enhance the experience of the physical space, as well as the emotional connection, and reinforce the museum's unique value proposition by fostering the relationship between the museum and the visitor.

To facilitate fruitful interaction, museums are using various digital data generation and processing technologies to provide more engaging and personalised experiences. In the past, telecommunication technology facilitated the development of virtual museums, and several researchers focused their studies on this area (Wu, 2017; Grincheva, 2018; Lee *et al.*, 2019; Wiastuti *et al.*, 2020; Tong & Ma, 2021). Today, research is focused on the application of AI in museums due to its development potential (Zhao *et al.*, 2022) and on the impact of AI on human artists and how the concept of authorship will evolve (Golgath, 2023).

The use of artificial intelligence in museums is still in its infancy, but it is already transforming the way visitors interact with exhibits and artworks in the museums where these experiences take place. The use of AI provides visitors with a deeper understanding of historical and cultural significance, as well as offering more interactive learning opportunities (Aristova *et al.*, 2020). AI technologies such as virtual reality, augmented reality, natural language processing and machine learning, combined with applications such as chatbots, not only provide a convenient interface for interactions between people and physical exhibits, but AI is also the core technology that imbues digital objects with intelligence.

Art Interactive devices, which help people discover and interact with the hidden stories behind works of art, are among these new technology-enabled interaction designs (Cepeda, 2020). As a result, museums can connect with a wider and more diverse audience, making education and cultural appreciation more accessible to people from all walks of life. AI has also facilitated the conservation and restoration of fragile works of art, ensuring that future generations can continue to benefit from these precious pieces of history. The integration of AI in museums is a promising development in the field of cultural heritage that promises to shape the future of museum visits for generations to come (Aristova *et al.*, 2020)

2.2.1. AI applications in museums

Museums are increasingly using artificial intelligence (AI) to enhance the visitor experience, as well as to monitor collections and provide educational resources. AI-powered tools include virtual guides, automated curation and personalised recommendations, all of which aim to make museum visits more engaging and informative for visitors (Dale, 2019; Li 2023; Lu, 2021). AI has the potential to revolutionise the museum experience, offering interactive and personalised features that adapt to visitors' diverse interests and preferences. In addition, AI can streamline administrative tasks and improve collections management, providing museums with valuable information and data-driven decision-making tools.

As technology continues to advance, the integration of AI in museums is likely to become even more prominent, offering innovative solutions for visitor engagement, educational outreach and operational efficiency. This shift towards AI in the museum industry may also lead to the creation of new jobs and skill requirements for museum staff as they adapt and adopt these technological advances. Ultimately, the incorporation of AI in museums represents a step forward in improving the overall visitor experience and ensuring the preservation and relevance of cultural institutions in the digital age (Suroto *et al.*, 2020).

Some examples of the application of AI technology in museums can be seen at the Dalí Theatre Museum, where they offer visitors a different experience by combining audio in post-cast format with virtual reality, augmented reality, micro-mapping, etc., (L_Bacchini, 2020). At the National Museum of Norway, autonomous learning and neural networks were used to add metadata to the paintings in the collection, very useful information for those studying them (L_Bacchini, 2020).

The Sao Paulo Art Gallery in Brazil has incorporated self-learning through AI to bring art to people who do not normally visit museums, giving them the opportunity to ask questions without feeling judged (L_Bacchini, 2020). The Smithsonian has developed humanoid robots such as Pepper, which it has placed in its museums in Washington: the National Museum of African Art, the National Museum of African American History and Culture, the Hirshhorn Museum and Sculpture Garden, and the Smithsonian Castle. Museum of Tomorrow in Rio de Janeiro incorporates chatbot to improve accessibility (EVE, 2023).

2.3. Educational innovation in museums

In recent years, education has seen significant advances with the emergence of AI and machine learning technologies. These advances have the potential to transform the way students learn and institutions teach, making education more personalised, effective and accessible. One promising application of AI and machine learning in education is the ability to personalise learning experiences for students. Educators can use these technologies to analyse large amounts of data and understand each student's individual learning styles and preferences, leading to personalised learning paths and content delivery.

This ultimately improves student engagement and understanding (Holmes *et al.*, 2019). By integrating AI and machine learning, museum institutions can offer a more personalised learning experience that meets the diverse needs of learners. These technologies can also streamline administrative tasks, freeing up time for educators to focus on individualised instruction and support. In addition, AI and machine learning can provide real-time feedback to both students and teachers, allowing for immediate adjustments and improvements to the learning process (Onesi-Ozigagun *et al.*, 2024).

In addition, the integration of artificial intelligence and machine learning technologies has the potential to provide valuable information to educational institutions, enabling them to continuously improve their teaching approaches and curricula using real-time data and feedback (Chen *et al.*, 2020). Therefore, the incorporation of AI and machine learning technologies has the potential to provide valuable information to educational institutions, allowing them to continuously improve their teaching approaches and curriculum using real-time data and feedback. By harnessing these technological advances, the education sector can work to create a more personalised, efficient and inclusive environment for both students and educators. Using these technological advances, the education sector can work to create a more individualised, efficient and inclusive environment for both students and educators (Shuford, 2023).

Virtual museums play a crucial role as powerful educational tools, offering engaging and immersive experiences (Yang *et al.*, 2023). Leveraging technology, these virtual platforms provide unprecedented access to cultural content and support educational objectives through interactive exhibits and digital resources. As technology continues to advance, virtual museums now offer realistic and intricate experiences that allow visitors to delve deeper into artefacts and works of art in ways never before possible. Using virtual reality and augmented reality, users can interact with historical events and cultural heritage in a more engaging and dynamic way (Giannini & Bowen, 2022).

These virtual experiences not only enrich learning, but also broaden access to cultural heritage for diverse audiences, transcending physical barriers and limitations. Virtual museums are revolutionising the way we engage with history and art, allowing people from all walks of life to explore and appreciate the richness of our collective heritage. Combining the traditional with the cutting-edge, virtual museums are shaping the future of education and cultural preservation, enabling people to connect with the past in a meaningful and powerful way. Through these digital portals, people can step back in time and immerse themselves in different cultures, gaining a deeper understanding and appreciation of the world around them. The possibilities of virtual museums are endless, opening new avenues of exploration and discovery that were previously unimaginable. As technology continues to evolve, virtual museums will continue to evolve in parallel, constantly pushing the boundaries of what is possible and reshaping the landscape of cultural education for generations to come (Daniela, 2020).

AI can also personalise the museum experience by recommending related content based on visitors' interactions and preferences. In addition, AI can help preserve historical artefacts through virtual restoration and conservation techniques. AI can also analyse visitor feedback and sentiment to improve the overall museum experience. AI can streamline ticketing and registration processes through automated systems and reduce waiting times. AI can also be used to create dynamic and interactive digital exhibitions that can be accessed online, reaching a wider audience and increasing engagement. AI can improve accessibility by providing language translation services for non-English speaking visitors.

AI can also ensure the safety of museum artefacts by monitoring and detecting unusual behaviour or threats. AI can help create virtual reality experiences that allow visitors to explore historical events or artefacts in an immersive way. AI can optimise visitor flow within the museum by analysing crowd patterns and suggesting ways to improve navigation and reduce congestion. AI can also personalise the museum experience by recommending related content based on visitors' interactions and preferences. In addition, AI can help preserve historical artefacts through virtual restoration and conservation techniques. AI can also analyse visitor feedback and sentiment to improve the overall museum experience (Centorrino *et al.*, 2021).

In addition, AI can create interactive tours tailored to visitors' individual interests and preferences. This can enhance educational programmes by customising content based on visitor demographics and learning styles, creating a more personalised and engaging experience. AI can also provide real-time information and updates on exhibitions and events, improving visitor satisfaction and engagement (Yau *et al.*, 2021). In addition, AI can analyse visitor comments and sentiment through social media and online platforms, allowing museums to better understand their audiences and make data-driven decisions to improve future experiences.

AI can also help preserve cultural heritage by digitising and restoring artefacts, making them accessible to a global audience. AI can also support conservation efforts by monitoring environmental conditions and identifying potential threats to museum collections. It can also analyse visitor behaviour and preferences to recommend personalised visits to exhibitions. In addition, AI can provide real-time translation services for international visitors, making museum exhibitions more accessible to a diverse audience. These advanced AI technologies have the potential to significantly transform the museum experience and contribute to the preservation and accessibility of cultural heritage for people around the world.

AI can play an important role in developing interactive exhibits that respond to visitor actions such as gestures, facial expressions and voice commands. By using AI technology, these exhibits can provide a more engaging and interactive experience for visitors. In addition, AI can be used to create virtual reality exhibits that allow visitors to travel to different historical periods, allowing them to learn and explore in a unique way. AI also has the potential to analyse visitor interaction with interactive exhibits, providing valuable information that can be used to improve future exhibit designs and the overall visitor experience (Wang *et al.*, 2023). AI can provide personalised recommendations for museum activities and content based on visitors' interests and preferences, tailoring the experience to individual needs.

In addition, AI can be used to create interactive exhibits that provide historical and cultural information in an engaging and informative way, further enhancing the educational and entertaining aspects of the museum experience for visitors. Using AI, museums can provide enhanced accessibility features for visitors with disabilities, ensuring that all people can fully participate in and enjoy exhibitions. In addition, AI technology can enable museums to collect and analyse data on visitor behaviour and preferences, allowing for continuous improvement in exhibition design and curation to better meet the evolving interests of museum visitors. These advances in AI applications can revolutionise the way museums interact with their visitors, creating memorable, personalised experiences that meet a wide range of interests and needs.

2.3.1. *The benefits and the challenges*

The integration of Artificial Intelligence (AI) in educational and museum contexts offers a wide range of benefits, including but not limited to improved accessibility, personalised learning experiences and increased engagement. However, it is important to recognise and address challenges such as data protection, ethical considerations and the need for technical expertise to maximise the potential of AI in these settings. By addressing these challenges, we can ensure that AI enhances the educational and museum experience for all stakeholders (Fernández, 2024).

The use of AI can also streamline administrative tasks, provide valuable insights through data analysis, and create more interactive and immersive experiences for learners and other visitors. In addition, AI can assist in the development of adaptive learning systems that cater to individual learning styles and abilities, ultimately leading to more effective education and engagement. However, it is crucial to balance the benefits and challenges of integrating AI into educational and museum settings to ensure that it is used responsibly and ethically, maximising the potential for improvement while minimising the risks. This will require collaboration between educators, technologists, policy makers and other stakeholders to develop guidelines and best practices for the use of AI in these contexts. Ultimately, the successful integration of AI in education and museum environments has the potential to revolutionise the way we learn, teach and experience cultural institutions, making knowledge and art more accessible and engaging for everyone.

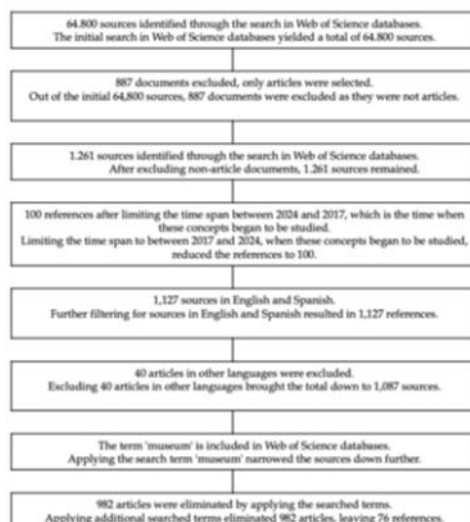
3. Methodology

The implementation of artificial intelligence in the museum environment has led to significant advances in visitor engagement (Allal-Chérif, 2022). This scientific article presents a systematic review (Marín, 2022) using the PRISMA 2020 protocol (Page *et al.*, 2021; Yepes-Núñez *et al.*, 2021), together with specific guidance from the PRISMA-ScR extension for exploratory reviews (Tricco *et al.*, 2018) and the PRISMA-S extension for literature searches (Rethlefsen *et al.*, 2021). The PRISMA-P protocol was used in the planning phase (Moher *et al.*, 2015).

The search strategy was agreed by the authors and carried out by one of them. The databases used were Web of Science (WOS), Dialnet, EBSCO and ERIC, covering documents from 2017 to the present. Searches were conducted in both English and Spanish, and eligibility criteria included primary studies on ICT and new AI applications in museum education. To ensure the representativeness of the articles selected for this study, we followed the steps suggested by Page *et al.*, 2021, who recommend the use of the PRISMA methodology for systematic literature reviews, as shown in Figure 1.

Figure 1.

Flow Diagram



Source: own elaboration (2024)

The first step was to identify the articles to be included in the study. A keyword search was carried out in the Web of Science and Scopus databases, two of the most relevant academic databases recognised for systematic reviews and bibliometric analysis. These were combined using the database operators to ensure a variety of output results. The inclusion criteria were the presence of these keywords in the "Title, Abstract or Keywords" section of the articles. The search criteria used are shown in Table 1. The number of papers retrieved from this initial search was 105.

Table 1.

Search and inclusion/exclusion criteria

Database	Web of Science (WoS)
Geographical range	Global scientific production
Characteristics	JCR Impact Factor JCR Immediacy Index Citations Quartile
Search Criteria	Subject
Inclusion criteria	Article
Time period	2017-2024
Search language	Spanish and English
Search date	June 2024
Keywords	TS = (artificial intelligence OR museum OR digitalization AND education)
First documents	105
Refinement	Duplicate documents, not related to the subject
Final documents	76

Source: own elaboration (2024)

Subsequently, duplicate articles were eliminated, i.e. those that did not relate to the research, despite containing the keywords, because the focus was different. Finally, a full reading of the articles was carried out to obtain the final sample for the systematic review and bibliometric study.

The final sample for analysis consisted of 76 articles. The bibliometric indicators used are Main Lines of Production, Article Productivity, Journal Productivity, Author Productivity, Social Analysis of Collaboration, Regional and Academic Productivity.

4. Results

The main lines of productivity

Figure 2 reflects the agreement found in the keywords of the 76 articles during the period 2017-2024 on artificial intelligence, museums and education. The field of computer science artificial intelligence stands out with 38 publications, followed by computer science interdisciplinary applications and computer science theoretical methods with 14. The most related to education and art add up to 11, which reflects that the scientific academy is at the forefront of research on the application of AI in education and museums.

Figure 2.

Productivity lines



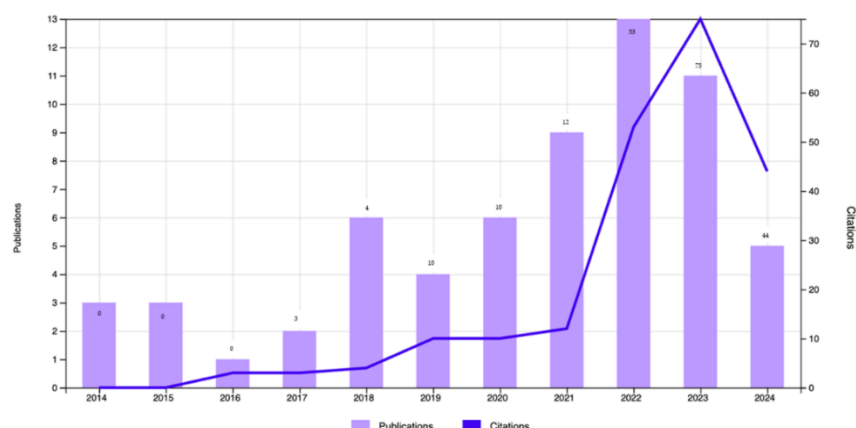
Source: Web of Science (2024).

Productivity of the articles

In the first years, from 2014 to 2017, the publication of articles is very low. From 2018 onwards, the interest in AI and education in museums starts to increase, with 2022 and 2023 being the most productive years in terms of production.

Figure 3.

Publications and citations



Source: Web of Science (2024).

The graph provides a detailed yearly breakdown of publications from 2014 to 2024. In 2014, the graph starts with 3 publications, and this number remains unchanged in 2015. However, in 2016, there is a drop to 1 publication, followed by a slight increase to 2 publications in 2017. A significant rise occurs in 2018, with the number of publications reaching 5. This is followed by a slight decrease to 4 publications in 2019, and then another increase to 5 publications in 2020. In 2021, there is a notable rise, with the number of publications reaching 8. The peak year is 2022, with 12 publications. This is followed by a slight decline to 10 publications in 2023, and as of 2024, there are 4 publications, which might be due to partial data for the year.

From 2014 to 2017, the number of publications remains relatively low and stable, fluctuating between 1 and 3 publications annually. Starting from 2018, there is a clear upward trend in the number of publications, peaking in 2022. However, the graph shows a decrease in 2023 and a more significant drop in 2024, which might be because the data for the year is incomplete. Alongside the publications, the graph also tracks citations with a line. The number of citations generally follows the trend of publications but peaks in 2023, indicating that the research from previous years is still being heavily referenced.

Figure 4.

Productivity by Journals



Source: Web of Science (2024).

The Figure 4, use a treemap graph visualizes the distribution of the 76 articles across various publishers. Springer Nature emerges as the most prolific publisher with 22 publications, occupying the largest segment in the treemap. IEEE follows as the second most significant publisher, contributing 13 publications. MDPI also has a notable presence with 9 publications. IOS Press has a moderate number of articles, totaling 5 publications. Other publishers like Assoc Computing Machinery (ACM) and Elsevier each contribute 3 publications. Smaller segments in the treemap represent publishers such as Hindawi Publishing Group, World Scientific, and Taylor & Francis, each with 2 publications. The treemap provides a clear visual representation of how the publications are concentrated among these publishers, highlighting the dominance of Springer Nature and IEEE in this dataset.

Productivity by authors

Regarding the distribution by authors, the 76 articles are signed by a total of 292 different authors, among which Emerson, Henderson, Giannini, Bowen, Heimbürger, Ioannakis, Bampis, Koutsoudis and Srivastava stand out as the most signed authors with 2 publications.

Table 2.

The most prolific authors

Authors	Number of articles that have been signed
Emerson, Henderson	2
Giannini, Bowen	2
Heimbürger	2
Ioannakis, Bampis, Koutsoudis	2
Srivastava	2

Source: own elaboration (2024).

Collaborative Social Analysis

Of the 76 articles analysed, 9 authors published 2 articles and the rest signed one article. This shows that there is a lack of systematicity or that the topic is very new.

The total number of signatures in the articles is 292, giving a collaboration index of 3.84.

Table 3.

Productivity of original articles

Authors	Nº of Jobs	Authors			
			n		%
Large producers	10 o more		0		0
Medium producers	2-9		9		3,1
Small producers	1		283		96,9
Total			292		100

Productivity by Regions and Academia

Research productivity varies significantly across different regions, with North America, Europe, and Asia leading the way due to their well-established research infrastructures and significant investments in science and technology. In North America, the United States and Canada dominate the research landscape with numerous prestigious universities and research institutions. Europe follows closely, with the United Kingdom, Germany, and France making substantial contributions through their renowned academic and scientific institutions.

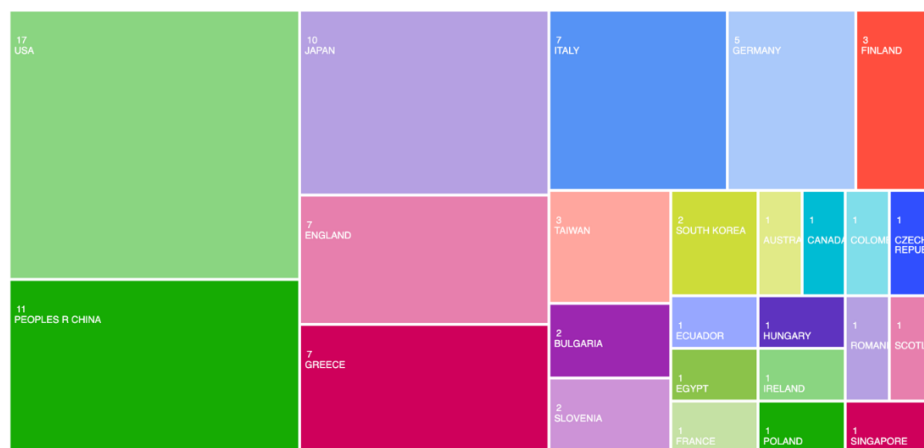
Asia has seen a remarkable increase in research productivity, particularly in countries like China, Japan, and South Korea, driven by extensive investments in scientific research. While regions like South America, Africa, and Oceania contribute less to volume, countries such as Brazil, South Africa, and Australia have notable research outputs that highlight their growing importance in the global research arena.

Academic contributions to research productivity are predominantly driven by universities, research institutes, and collaborative networks. Prestigious universities such as Harvard, MIT, Stanford, and Oxford are at the forefront of research output, benefiting from significant funding, advanced facilities, and a strong culture of innovation. Dedicated research organizations like the Max Planck Society in Germany and the National Institutes of Health (NIH) in the United States play crucial roles in producing high-impact research.

The increasing trend of international collaborations and partnerships between academia and industry further boosts research productivity, leading to more comprehensive and impactful studies. Government and private funding, provided by agencies like the National Science Foundation (NSF) and foundations such as the Bill & Melinda Gates Foundation, are essential in supporting these research activities, underscoring the interconnectedness of funding, infrastructure, and collaborative efforts in enhancing academic productivity.

Figure 5.

Countries



Source: Web of Science (2024)

5. Discussion

Nowadays, museums have undergone major changes to adapt to the demands of their visitors, who want different experiences and social benefits (Kotler, 2021). Therefore, they have had to adapt to technological changes by incorporating ICT in their strategy, especially the web and social networks (Fernandez-Lores *et al.*, 2022), virtual communities (Fernández-Hernández *et al.*, 2020). In recent years, the challenge has been to implement AI technologies such as augmented reality, virtual reality, chatbots, which create experiences where the visitor can interact (García-Pereira *et al.*, 2020), increasing the satisfaction of the visit.

It also helps the museum to personalise learning in adaptive environments (Hufschmidt, I., 2023), which increases the engagement of training participants and improves learning outcomes (Chen *et al.*, 2020; Brown *et al.*, 2018; Holmes *et al.*, 2019). Experiences have already been created in various museums using AI technology, such as the Dali Theatre Museum, the National Museum of Norway, the Smithsonian and the Sao Paulo Art Gallery in Brazil. Experiences that have rewarded visitors by allowing them to share their experiences with other visitors, thus generating more interest, which translates into an increase in museum attendance.

One important aspect that AI can help with is making the museum more accessible, especially for people with disabilities who are unable to travel to the museum or see, hear and touch the artworks to understand them. By creating replicas of the artworks, the barrier of not touching them to avoid damaging them is broken, and through inverted exhibits and chatbots adapted for these people, their experience can be far more rewarding. The integration of artificial intelligence in education has the potential to revolutionize how students learn and engage with their environment. AI offers personalized learning experiences through adaptive environments and intelligent tutoring systems, which significantly enhance student engagement and improve learning outcomes (Chen *et al.*, 2020; Brown *et al.*, 2018; Holmes *et al.*, 2019).

AI's ability to personalize instruction and provide real-time feedback allows educators to monitor student progress closely and offer targeted interventions, thereby creating a more effective and personalized learning experience. Furthermore, AI can bridge the gap in access to quality education by providing resources and support to students in underserved communities. The potential of AI in transforming education and improving student outcomes is profound and presents endless possibilities for the future of learning (Holmes *et al.*, 2019). The methodology used shows how little scientific research there is on the subject, and that the output in leading journals is entirely in English.

5. Conclusions

This bibliometric study concludes that, in the last few years, 2022-2024, there has been an increase in scientific production on the subject studied. Of the articles studied, all are in English and none in Spanish, which shows a clear limitation of publications in that language. The journal with the most publications is Springer Nature with a number of 22 articles. The 76 articles studied were signed by a total of 292 authors, including Emerson, Henderson, Giannini, Bowen, Heimbürger, Ioannakis, Bampis, Koutsoudis and Srivastava. The collaboration index is 3.84 and the main lines of research have been Computer Science Artificial Intelligence.

In terms of theoretical implications, key findings suggest significant improvements in visitor engagement, satisfaction and educational outreach through interactive and personalised content. Despite challenges related to data authenticity, security and privacy, AI has immense potential to improve visitor engagement, heritage conservation, educational outreach and museum management. Further research and collaboration are essential to maximise the benefits of AI, while addressing the challenges it poses.

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Funding: This investigation received either. No financing external.

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