Article

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Exploring Design Aspects of Online Museums: From Cultural Heritage to Art, Science and Fashion

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Abstract: The article presents a perspective on online museum design by conducting a systematic review. The study aims to synthesize key findings related to online museums, focus on issues related to design as well as identify priority areas for further research in the design of online museums. The systematic review process followed the guidelines outlined in the PRISMA 2020 recommendations to select relevant articles. A search was conducted in the Web of Science database with the specific topic of "online museum design." A total of 148 publications published between 2019 and 2023 were identified and selected for the review. A keywords map was generated based on the bibliographic data of the selected articles. By conducting a systematic review of publications from the Web of Science database, the study identifies five clusters of research in online museum design. These clusters cover topics such as visitor behavior, accessibility, authenticity, immersive technologies, and technology adoption. The findings highlight key aspects of design that impact user engagement, cultural heritage, virtual reality, and the intersection of technology and tourism. The review also includes a case study of online museums representing various types of artifacts, including historical and cultural heritage, art, science, nature, clothing, and museums for children. Overall, the systematic review provides valuable insights for researchers, practicing designers, and museum professionals involved in creating and curating online museum experiences. Further research involves a review of publications using other scientific databases, as well as using the term "virtual museum" for a wider coverage of publications in this direction.

Keywords: cultural heritage; design; online museum; technology; virtual reality; web design

1 Introduction

The rapid development of digital technologies gives rise to new forms of access to the treasures of the world's arts and crafts, historical artifacts, and presentations of scientific achievements. Online museums have emerged as a dynamic and innovative way to engage audiences, provide access to artifacts of cultural heritage and modern art and science, and promote educational experiences. With the rapid advancements in digital technologies, museums have increasingly turned to online platforms to expand their reach beyond physical spaces. These virtual spaces allow visitors to explore exhibitions, interact with multimedia content, and participate in immersive learning experiences from the comfort of their own homes.

An online museum refers to a virtual platform or website that digitally replicates the experience of visiting a traditional museum. It allows users to explore and interact with collections, exhibits, and educational resources remotely, typically through the use of digital technologies such as multimedia content, virtual reality, and interactive features.

We used the term "online museum" in accordance with the findings of Sviličić's (2010) review, which justifies the correctness and broader dissemination of this particular name for a museum located on the Internet. However, in some studies, authors also use other terms that have slightly different nuances of meaning but can be considered synonymous with an online museum, such as "digital museum," "cyber museum," "web museum," "internet museum," "electronic museum," and "virtual museum."

The design of online museums plays a crucial role in shaping the visitor experience and ensuring effective communication of cultural narratives. Design aspects such as user interface, information architecture, interactivity,

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and visual aesthetics significantly impact users' engagement and understanding of the exhibited content.

The article by Moreno (2018) reflects on the changing role of museums in the digital age, where digital language has revolutionized the production, distribution, and conservation of contemporary art, challenging the traditional functions of museums as moral authorities and storage spaces for physical works, and emphasizing the need for museums to adapt to new digital contexts by offering practical databases and updated information on their collections via websites and social networks.

The article by Taormina and Baraldi (2022) presents a literature review on the organizational aspects of museums and digital technology, highlighting the increasing reliance on digital tools, particularly during the Covid-19 pandemic, and explores core topics such as business models, digital professions, and digital strategy, ultimately providing implications for museums, policy makers, and scholars.

The advent of online platforms and virtual technologies has provided museums with new opportunities to engage with visitors and extend their reach beyond physical spaces. The next studies contribute to the development and improvement of online platforms and technologies for online museums, enhancing the accessibility, engagement, and preservation of cultural heritage content.

Pisoni et al. (2021) conducted a literature review on technology in museum and cultural heritage experiences, emphasizing the significance of inclusive delivery and the potential of Artificial Intelligence (AI) advancements to enhance accessibility, proposing a conceptual framework. Zhao and Yezhova (2024) find that the integration of artificial intelligence in online museum design significantly enhances the artistic components of digital exhibits by dynamically adapting visual content and design elements to align with viewers' preferences, thereby creating more engaging and aesthetically rich user experiences.

Venigalla and Chimalakonda (2019) proposed the concept of an Augmented Reality Museum (ARM) to enhance the user experience of online museums. The study demonstrated the potential of AR technology to improve user experiences in online museums.

Kutzner et al. (2021) conducted a literature review and examined online platforms to develop a taxonomy of how they facilitate cultural participation and education, aiming to guide platform designers and museum professionals in creating online experiences that support the "museum experience" while considering resource limitations and challenges faced by museums.

Champion and Rahaman (2020) addressed the critical analysis and evaluation of existing 3D model portals and online repositories for digital heritage. They highlighted the lack of recent academic publications that assess the potential of these platforms and their functionalities in advancing the field of digital heritage.

Lu et al. (2021) proposed a novel interaction concept called GazeTance Guidance for virtual museums. This concept utilized users' gaze points and interaction distance to enhance the appreciation of artworks. The study demonstrated improved memory performance on regions of interest with the guidance approach without compromising presence and user experience.

Aristeidou et al. (2021) examined the participation patterns and contribution of young volunteers in citizen science using the iNaturalist platform facilitated by museums. They compared the observation behavior of young volunteers with that of all iNaturalist users and identified differences in the types of organisms observed. The study found insights into young volunteers' contributions to citizen science and offered implications for designing museum field-based events to encourage continued participation.

McKenna, Debruyne, and O'Sullivan (2022) focused on using linked data (LD) to enhance data discoverability and resource sharing in libraries, archives, and museums (LAMs). They introduced the Novel Authoritative Interlinking for Semantic Web Cataloguing in Libraries (NAISC-L) framework which was specifically designed for LAMs. The authors conducted user-experiments involving information professionals to evaluate the framework's effectiveness and usability, demonstrating its usefulness for creating richer and more authoritative interlinks between LAM resources.

The study by Zhitomirsky-Geffet, Kizhner, and Minster (2023) examined the level of bias in six online databases from two major art museums by applying ethical criteria, revealing variations in bias across the databases and highlighting the importance of addressing bias in cultural heritage representation through online channels.

Viñals et al. (2021) proposed the "Avatar Tourist Visit" model, combining interpersonal communication, filmmaking, audio-visual language, and information and communication technologies to create sustainable tourist experiences.

Damala, Ruthven, and Hornecker (2019) presented the MUSETECH model, a comprehensive evaluation framework for museum technology. The framework considered the perspectives of cultural heritage professionals, cultural heritage institutions, and museum visitors in evaluating digital technologies before and after their introduction into a museum setting.

Puggelli, Furferi, and Governi (2019) proposed a portable, affordable device for capturing 3D geometry of paintings on canvas in cultural heritage applications. They presented a procedure based on laser-camera triangulation

and fiducial markers to acquire and triangulate 3D data for documentation and preservation purposes.

Johnson and Liew (2020) focused on design recommendations for crowdsourcing platforms in cultural heritage institutions (CHIs). The authors derived design recommendations and classified them into four categories: promoting ease of use, attracting and sustaining user interest, fostering a community of users, and demonstrating the impact of user contributions.

Deligiannis et al. (2020) presented "Hydria," an online data lake designed to manage and analyze heterogeneous, multi-faceted cultural heritage data. The system allowed users without an IT background to acquire, store, organize, analyze, and share cultural heritage data effectively.

Varma, Chauhan, and Yafi (2021) introduced ARTYCUL, a privacy-preserving machine learning framework that determined the popularity of a cultural exhibit on display. The framework utilized video streams from closed-circuit television (CCTV) cameras installed at cultural heritage sites to detect human figures and visualize the density of visitors around specific artifacts.

Sprugnoli et al. (2021) focused on using a digital game, PAGANS, to collect visitors' feedback on artwork similarity in a museum environment. The game engaged users in playful interactions with artworks and gathered data on their judgments of similarity. The collected information aided curators in rethinking digital exhibitions and understanding visitors' aesthetic perception.

Seo and Rhee (2022) proposed schemes to improve the streaming experience in path-walking virtual reality (VR) systems by considering the viewer's movement patterns, including a caching strategy based on geometrical locality and adjusting image quality based on viewer speed and head direction, offering insights for the design of interactive streaming systems for immersive media applications, in particular, for online museums.

Cho et al. (2019) presented an interactive exhibition concept that utilized existing physical wall panels in a museum. The authors combined unique exhibition contents with rendering and interface techniques to create immersive experiences with two-way communication and multi-modal feedback.

Flouty (2019) presented a case study of The Broad Museum's Online Learning Management System (LMS) Training Tool, emphasizing the importance of training front-line staff to engage with visitors effectively.

The article by Symeonidis et al. (2022) presented V4Design, a framework that enables the automatic analysis, linking, and transformation of heterogeneous multimedia content for creative industries, including architecture and gaming, aiming to support the design process and draw inspiration from online museums and other digital sources.

Marty and Buchanan (2022) emphasized the role of museum technology professionals during Covid-19 crises, focusing on digital literacy skills, increased investment in digital technologies, and the development of digital strategies.

Of interest is research in the field of online museums in various areas, in particular clothes. The research of Wu et al. (2022) has demonstrated that the digitization of clothing collections by Digital Costume Museums (DCM) has led to enhanced understanding, enjoyment, and positive visitor attitudes. Furthermore, this digitization process has also stimulated further learning, experiential engagement, and research endeavors in the field of textile and fashion design. The article by Pashkevich, Yezhova, and Gerasymenko (2020) examined the use of information and communication technologies (ICT) in self-education and discussed the resources available for personal development and scientific research, including electronic databases, social networks, virtual museums, with a focus on fashion designers as an example. The effectiveness of using 3D design in the training of future designers was substantiated in the article by Kolosnichenko et al. (2021). Another article, by Gryshchenko et al. (2024), provides valuable information on the role of digital training for designers as part of an international educational project for the research, preservation, and dissemination of cultural heritage.

While numerous studies have explored various aspects of online museums, there is a need for a comprehensive overview of recent innovations in online museum design.

By conducting a systematic review, we aim to identify and analyze the latest research on online museum design, with a specific focus on innovations and advancements in user experience, interface design, interactive features, and content presentation. This review will provide valuable insights into the current state of online museum design practices and highlight areas for future research and development.

The purpose of this study is synthesizing key findings related to online museums, focusing on issues related to design, as well as identifying priority areas for further research in the design of online museums.

The research question is: what design aspects are important in designing an online museum and why? Or how can we use different design aspects in designing an online museum?

2 Methodology

To gather relevant studies, a systematic search was conducted using keywords related to online museum design in reputable academic database Web of Science. The selected studies were critically reviewed to assess their relevance,

quality, and contribution to the understanding of online museum design.

2.1 Eligibility Criteria

The selection of articles for the systematic review was carried out according to the PRISMA 2020 recommendations described in the article by Page et al. (2021). Scientific articles, the subject of which includes online museum design, were selected for review.

2.2 Information Sources

The search was carried out in the Web of Science database in June 2023.

In the search conditions, the topic "online museum design" is specified.

Publications for 2019–2023 were selected to identify the most relevant areas of scientific research and, as a result, 148 publications were selected for review and analysis by keywords. Also, cluster analysis of these 148 publications by keywords was conducted. As a result of the analysis of the texts of the articles, publications that did not correspond to the subject of this study were excluded. The remaining 78 publications were included in the text review. A textual overview of these publications is provided in the Introduction and Results sections.

2.3 Cluster Analysis Based on Bibliographic Data

At the next stage, in order to identify the most significant directions of scientific research in the field of online museum design, a cluster analysis was conducted on the selected 148 sources by keywords. To achieve this, the software tool VOSviewer (2024) was utilized to construct and visualize bibliometric networks. A keywords map based on bibliographic data on online museums design was created using the keywords from the selected publications.

The following resource settings are used: Minimum number of occurrences of a keyword: 3. Minimum cluster size: 6.

For cluster analysis, the list of keywords excludes words that do not outline the subject of the research but refer to general scientific categories ("science," "impact," "experience," "knowledge," "quality," "system," "tool") and direction of scientific research ("future"). Similar keywords were also changed, e.g. "cultural-heritage" to "cultural heritage," "museums" to "museum," and "technologies" to "technology."

Table 1: Key steps for a systematic review of online museum design (according to the PRISMA 2020 statement).

Identification of new studies via databases	Data analysis Type	Records removed
Records identified from Web of Science database (N = 312)	The distribution of articles by the year of publication The distribution of articles by WoS categories The distribution of articles by countries	Records marked as ineligible by automation tools (N = 164)
Records screened (N = 148)	Analysis of publications by keywords Cluster analysis by keywords Keywords map via VOSviewer	Records excluded by a human: Reason 1 – do not correspond to the subject of this study (N = 70)
New studies included in review (N = 78)	Textual overview	

The results of cluster analysis are presented in the table in the Results section and interpreted in the Discussion section.

The main stages of the systematic review of online museum design (according to the PRISMA 2020 statement) are organized in Table 1.

3 Results

3.1 The Distribution of Articles in Online Museum Design

According to the search results, 312 results were obtained.

The distribution of articles in online museum design by the year of publication is as follows (Figure 1). As seen in Figure 1, this distribution shows the number of articles related to online museum design published each year, with a peak in recent years (2021, 2022, and 2023) indicating a growing interest in the topic.

The results of the distribution of articles about the design of online museums by Web of Science Categories are shown in Figure 2.

These results indicate the interdisciplinary nature of research on the design of online museums. The articles are distributed across various disciplines such as education, information science, computer science, humanities, art, engineering, and hospitality. This reflects the diverse perspectives and approaches taken to explore and understand the design aspects of online museums. It also highlights the relevance of online museums in fields beyond traditional

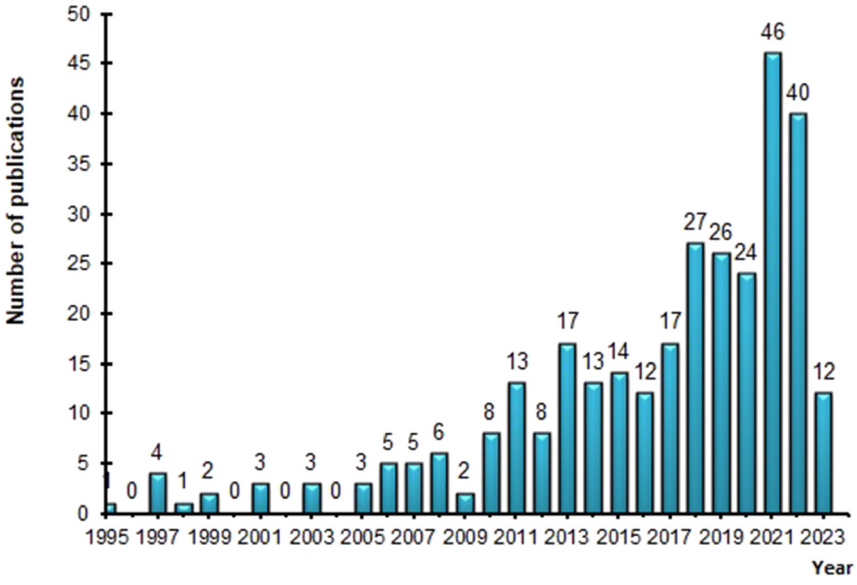

Figure 1: Distribution of online museum design publications by year (Web of Science, N = 312).

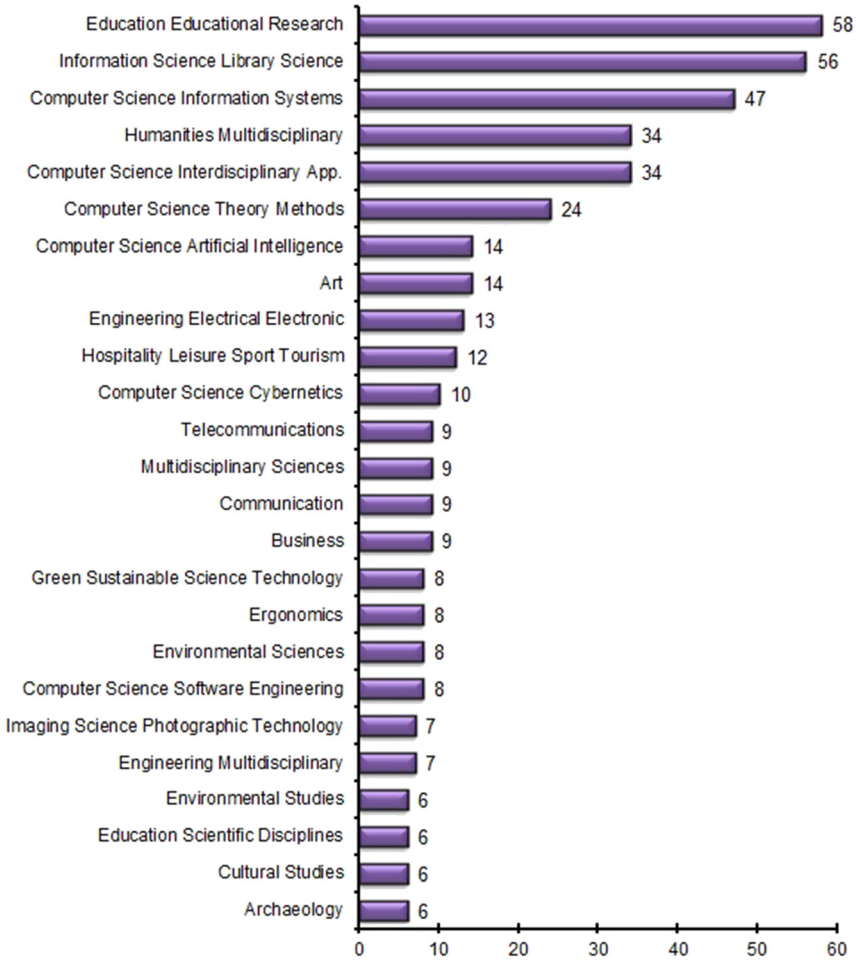

Figure 2: Distribution of search results for online museum design by WoS categories (Web of Science, N = 312, only top 25 categories are included).

museum studies, emphasizing the intersection of art, technology, education, culture, and other domains.

The distribution of search results for online museum design by countries is presented in Figure 3.

As seen in Figure 3, the distribution of articles on the design of online museums by countries shows that the United States has the highest number of publications (76), followed by England (41) and China (36). Australia, Spain,

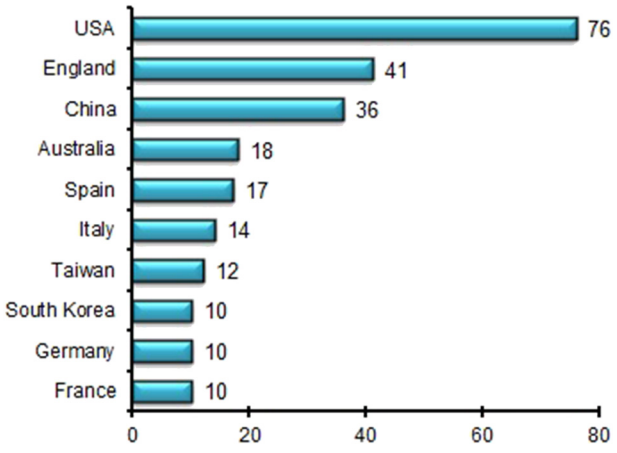

Figure 3: Distribution of search results for online museum design by countries (Web of Science, N = 312, only top 10 countries are included).

Italy, Taiwan, France, Germany, and South Korea also contribute significantly to the research in this field. Several other countries, including Greece, Netherlands, Malaysia, Norway, Turkey, Brazil, Canada, Japan, Mexico, and New Zealand, have made notable contributions as well. This distribution highlights the global interest and engagement in studying the design aspects of online museums.

3.2 Results of Analysis of Publications by Keywords

On the 868 keywords, 56 meet treshold 3.

In the analysis of articles about online museum design using keyword occurrence, we can observe that "museum" appears as the most frequent keyword, indicating its central role in the field of online museum design.

Other frequently occurring keywords include "design," "technology," "augmented reality," "cultural heritage," "impact," "model," and "virtual museum." These keywords represent core concepts and areas of focus in the research on online museum design.

Keywords like "engagement," "social media," "behavior," "virtual reality," "visitors," "education," "experience," "museology," "satisfaction," "science," "students," "tourism," "web," "conservation," "Covid-19," "digital cultural heritage," "environments," "heritage," "knowledge," "participation," "quality," "reality," "system," and "travel" have an average occurrence. These keywords indicate broader themes and areas of interest that are explored in the context of online museum design.

Keywords such as "accessibility," "authenticity," "bias," "citizen science," "cultural institutions," "future," "higher education," "information retrieval," "internet," "libraries," "motivation," "museography," "online," "online exhibition," "perceptions," "performance," "play," "sustainability," "technology acceptance model," "tool," "usability," "user acceptance," and "website" have a rarer occurrence. These keywords represent specific subtopics or emerging areas of research within online museum design.

The results of calculating the frequency of occurrence and total link strength of keywords in the studied 148 articles are shown in Table 2.

Table 2: Occurrences and total link strength for keywords (Web of Science, 2019–2023 years, N = 148, only keywords with at least three occurrences included).

Keyword	Occurrence	Total link strength
Museum	38	95
Design	14	33
Technology	11	35
Augmented reality	10	24
Cultural heritage	10	15
Impact	10	41
Model	10	30
Virtual museum	8	21
Engagement	7	18
Social media	7	22
Behavior	6	19
Virtual reality	6	20
Visitors	6	21
Education	5	10
Experience	5	23
Museology	5	10
Satisfaction	5	23
Science	5	7
Students	5	12
Tourism	5	14
Web	5	19
Conservation	4	9
Covid-19	4	11
Digital cultural heritage	4	8
Environments	4	18
Heritage	4	10
Knowledge	4	13
Participation	4	17
Quality	4	15
Reality	4	13
System	4	9
Travel	4	20
Accessibility	3	6
Authenticity	3	10
Bias	3	6
Citizen science	3	12
Cultural heritage	3	4
Cultural institutions	3	12
Future	3	8
Higher education	3	5
Information retrieval	3	3
Internet	3	12
Libraries	3	9
Motivation	3	13

Table 2: (continued)

Keyword	Occurrence	Total link strength
Museography	3	7
Online	3	8
Online exhibition	3	12
Perceptions	3	4
Performance	3	16
Play	3	12
Sustainability	3	12
Technology acceptance model	3	17
Tool	3	13
Usability	3	10
User acceptance	3	15
Website	3	13

After the exclusion from this list of words that do not characterize the subject of research (see more details in the Methodology section), 56 items were obtained, which form five clusters. The map of keywords built as a result of statistical analysis by the Vosviewer tool is shown in Figure 4.

The cluster analysis of articles about online museum design by keywords performed in Vosviewer resulted in five distinct clusters with a minimum cluster size of six keywords. The detailed results of cluster analysis of publications by keywords are presented in Table 3.

3.3 Results of a Review of Publications on the Design Aspects of Online Museum

3.3.1 Cluster 1

This cluster focuses on the behavior of visitors and users in online museums (Yi et al. 2022), including how they interact with digital platforms (Contu et al. 2019) and the impact of COVID-19 on cultural institutions (Tan and Tan 2021). It also includes research on design considerations (Giannini and Bowen 2023), digital cultural heritage (Morse et al. 2022), information retrieval (Golub, Ziolkowski, and Zlodi 2022), online exhibitions (Resta et al. 2021), social media usage (Schellnack-Kelly 2022), travel-related aspects, and the usability and design of museum websites (Gran et al. 2019). A number of studies (Coltofean-Arizancu, Mattioli, and Díaz-Andreu 2022) provide insights into the potential of social media platforms, such as Facebook, in raising awareness about wildlife conservation efforts (Schellnack-Kelly 2022) and archaeological projects. They emphasize the role of social media in raising awareness, disseminating knowledge, and engaging audiences in wildlife conservation and archaeological projects. The COVID-19 pandemic has posed significant challenges for museums worldwide, forcing them to reimagine their operations and find innovative ways to engage audiences. A number of studies investigate the

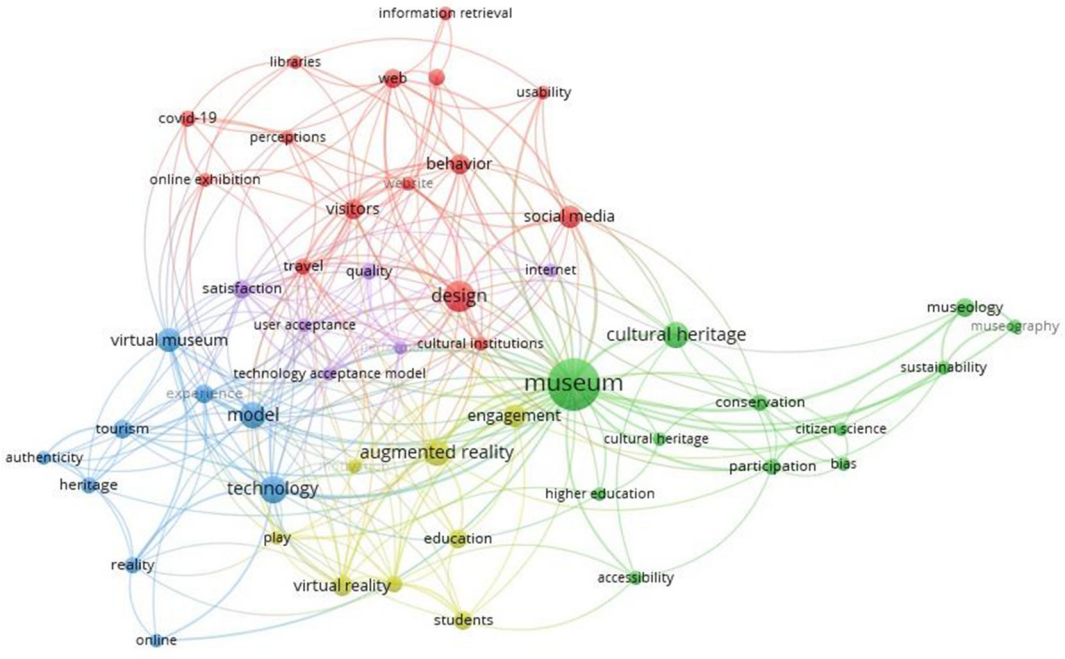

Figure 4: Keywords map based on bibliographic data, on online museum design (2019–2023, Web of Science).

Table 3: Keyword clusters of online museum design publications (Web of Science, 2019–2023 years, N = 148, only keywords with at least of three occurrences included).

Cluster 1–15 items	Cluster 2–12 items	Cluster 3–9 items	Cluster 4–8 items	Cluster 5–6 items
Behavior	Accessibility	Authenticity	Augmented reality	Internet
Covid-19	Bias	Experience	Education	Performance
Cultural institutions	Citizen science	Heritage	Engagement	Quality
Design	Conservation	Model	Environments	Satisfaction
Digital cultural heritage	Cultural heritage	Online	Motivation	Technology acceptance model
Information retrieval	Cultural heritage	Reality	Play	User acceptance
Online exhibition	Higher education	Technology	Students	
Perceptions	Museography	Tourism	Virtual reality	
Social media	Museology	Virtual museum		
Travel	Museum			
Libraries	Participation			
Usability	Sustainability			
Visitors				
Web				
Website				

Table 4: Main results of articles whose keywords belong to cluster 1.

Reference	Keywords	Main funding
Li, Nie, and Ye (2022)	Design	While an online virtual museum tour of the Exhibition of Architecture of the Forbidden City effectively combines authenticity, interactivity, navigation, and learning, it requires improvements in behavioral authenticity, navigation design, and inclusivity.
Contu et al. (2019)	United Nations Educational, Scientific and Cultural Organization (UNESCO); natural and cultural heritage; websites; museum websites, online popularity; cluster analysis; classification tree, technology; design	UNESCO heritage sites in France, Italy, and Spain primarily create websites to provide general and touristic information but often lack engaging content and interactive elements which are crucial for achieving online popularity and enhancing tourist attraction.
Waller and Waller (2021)	Museums; music; visitors; David Bowie, popular-music heritage; art-museums; artification; exhibitions; reviews; memory; media	The new conceptual framework for understanding visitor experiences at pop culture exhibitions, particularly those related to music, by analyzing visitor feedback and linking tangible and intangible elements such as songs, costumes, and cultural context, with practical implications for museums in curating engaging exhibitions.
Kiefer (2020)	Digital curation; Belgian Congo; world's fair; museum community engagement; panoply display; colonial ethnography	The Royal Museum for Central Africa's online curation tool, intended to share curatorial control, inadvertently juxtaposes items with traumatic histories without critical context, reflecting issues similar to those found in Belgium's 1897 colonial exposition.
Golub, Ziolkowski, and Zlodi (2022)	Digital cultural heritage; online museums; search interfaces; subject searching; controlled vocabularies; information retrieval; image retrieval	The study examined the search interfaces of Swedish online museum collections, emphasizing the need for improvements in search interfaces and the implementation of controlled vocabularies.
Ma and Hu (2022)	Cultural-heritage; visitors; fuzzy	The content, completeness, and update speed of 115 national museums in China were crucial factors influencing the measurement of the museum website's utility index, highlighting the importance of comprehensive, accurate, and timely information
Gran et al. (2019)	Digital museum; digital infrastructure; museum websites; museum users; visitor studies; cultural diversity	The study demonstrates how dDigital Museum enhanced Norwegian cultural diversity in terms of content and purpose for usage.

Table 4: (continued)

Reference	Keywords	Main funding
Nubani and Ozturk (2021)	Museum visitor emotions; facial expression detection; self-experimentation; museum design; exhibit design	Capturing architectural details and exhibit transitions can make virtual visits as engaging as in-person visits.
Garcia-Madariaga et al. (2019)	Trust; e-loyalty; website quality; multi-group analysis; museums; perceived control	The study highlights the significance of website quality in influencing user behavioral outcomes and perceptions.
Yi et al. (2022)	Aesthetic preference; art; behavior; liking	The study explores the impact of visitor-based social contextual information (VSCI) on museum experiences, highlighting the positive influence of VSCI in facilitating interactions, providing new perspectives, and enhancing the overall visitor experience, with implications for the design of strategies to enrich museum visits in an online context.
Du, Zhou, and Li (2022)	Fogg's behavior model; user type evaluation; cultural and creative product design	The evaluation model for museum online users based on Fogg's behavior model.
Giannini and Bowen (2023)	Art and technology; computational culture; cultural conflict; digital culture; digital identity; human behavior; interdisciplinary studies; museums	In the face of global cultural conflicts and digital identities, museums must consider visitor interactions, rethink institutional priorities, and adapt to the changing cultural landscape.
Tan and Tan (2021)	Museum; wellbeing; technology; Covid-19; Singapore	Highlighted the role of museums as public health resources, emphasizing the benefits of technology in providing social connections and meaningful engagement during periods of isolation.
Morse et al. (2022)	Digital museums; digital cultural heritage; museum experience design	While museums increased their use of digital technologies during the Covid-19 confinement period, these solutions were largely seen as temporary substitutes rather than permanent innovations, with successful digital engagement stemming primarily from activities that fostered community and visitor self-expression.
Li et al. (2022)	Covid-19; online exhibition; psychological distance; electroencephalography (EEG); user engagement (UE); user experience (UX); moire patterns	The study explores the impact of psychological distance and user engagement in online exhibitions, introducing a media device to enhance user experiences.
Coltofean-Arizancu, Mattioli, and Díaz-Andreu (2022)	Social media; Facebook; marketing plan; rock art research; archaeoacoustics; communication; dissemination; artsoundscapes	In the study a marketing plan is implemented for social media, specifically the Facebook page of the ERC Artsoundscapes project, which focuses on communicating and disseminating archaeological knowledge.
Schellnack-Kelly (2022)	Social media; information seeking; information sharing; conservation; SCOPE framework; cultural heritage	The study demonstrates how social media platforms play a crucial role in nature conservation by offering educational experiences and facilitating public engagement with a national game reserve in South Africa, effectively turning it into a living museum.
Westerby and Keegan (2019)	Art institute of Chicago; museum collection catalogues; digital publishing; digital archives; impressionism	The study examined the impact of digital scholarly collection catalogs at the Art Institute of Chicago on art history in the digital realm.

impact of the pandemic on museum design and the adoption of digital technologies (Li et al. 2022). An overview of the most typical articles whose keywords belong to Cluster 1 is given in Table 4.

3.3.2 Cluster 2

This cluster explores topics related to accessibility and inclusivity in online museums, addressing issues such as bias and ensuring equal access to cultural heritage. It also covers aspects of citizen science (Aristeidou et al. 2021), conservation of digital cultural heritage (Moreno 2018), education's role in online museum practices (Szalbot 2022), museography (García Aguinaco 2021), museology (Valtysson 2022), museum participation, and sustainable approaches in the context of online museum design (Cappa, Rosso and Capaldo 2020).

Table 5 provides a detailed overview of the most representative articles associated with the keywords in Cluster 2.

Table 5: Main results of articles whose keywords belong to cluster 2.

Reference	Keywords	Main funding
Jorente and Kahn (2019)	Brazil; digital curation; information and technology; information, design; museological fact; Museu da Pessoa	Information Design plays a crucial role in the Digital Curation of Museu da Pessoa, facilitating the organization, preservation, and interactive access to life stories as cultural heritage within a dynamic Web 2.0 environment.
Valtysson (2022)	British Museum; collections; digital communication; digital cultural politics; museology; museums; National Museum of Australia; platforms; policies	While the British Museum and the National Museum of Australia articulate democratic, participatory, and user-generated digital communication policies, there is a disconnect between these policies and their actual practices in the design of digital collections and social media use.
Petrelli (2019)	Tangible and embodied interaction; Internet of Things; cultural heritage; museum; multisensory; affective interaction	The study emphasizes the integration of interactive experiences using technologies like the Internet of Things and multisensory approaches to enhance visitor engagement.
Cappa, Rosso, and Capaldo (2020)	Open innovation; open innovation in science; cultural heritage organizations; sustainability; museums; managerialization; sustainable development goals; Agenda 2030	The concept of "visitor-sensing" for involving visitors in cultural heritage organizations.
Szalbot (2022)	Old photography; museum online; cultural heritage in lockdown; participatory museum; reconstruction of past games and toys	The study explores the use of archival photographs in museum education and the development of lesson scripts using design thinking.
García Aguinaco (2021)	Museums; museography; exhibition design; sustainability; museology; interpretation; audiences	The study reflects on the challenges faced by museums in exhibition design during the pandemic.
Fabra and Zabala (2019)	Multivocality; museography; museology; heritage education; public archaeology	The study discussed a collaborative project conducted with community and museums in Cordoba, Argentina, aiming to promote dialog, multivocality, and the recovery of local bioarchaeological heritage knowledge through an itinerant exhibition, a documentary, and an online publication.

3.3.3 Cluster 3

This cluster examines the concept of authenticity (Dağ, Çavuşoğlu, and Durmaz 2023) and user experiences (Pan and Luh 2020) in online museums. It explores how technology can be used to provide virtual heritage experiences (Yang and Zhang 2022), the modeling of digital cultural heritage, the use of online platforms (Massari, Del Vecchio, and Degl'Innocenti 2022), and virtual reality in the context of online museums. It also includes research on the intersection of technology, tourism (Massari, Del Vecchio, and Degl'Innocenti 2022), and virtual museums (Kim and Hong 2020).

Table 6: Main results of articles whose keywords belong to cluster 3.

Reference	Keywords	Main funding
Yang and Zhang (2022)	Smart tourism technologies; smart museum; servicescape; memorable tourism experiences; revisit intention; PLS-SEM	The positive impact of smart tourism technologies on creating memorable museum experiences has been highlighted.
García-Bustos et al. (2023)	Virtual museum; virtual exhibition; Palaeolithic art; parietal art; portable art; photogrammetry	The article focused on democratizing and making Franco-Cantabrian Palaeolithic art more accessible through the creation of a virtual museum.
Resta et al. (2021)	Virtual tour; digital twin; online exhibition; engagement; museum digitization	The study examines the engagement level of virtual tours in museums, focusing on factors such as the representation of architectural space, representation artifacts, and ease of use, specifically in the case of the archaeological museum of Troya Müzesi in Çanakkale, Turkey.
Massari, Del Vecchio, and Degl'Innocenti (2022)	Museum; digitalization; value co-creation; interaction; tourism destination	Digital technologies can transform museums into "interaction platforms," emphasizing the co-creation of value in tourism destinations, with empirical evidence from the National Archeological Museum of Taranto.

Table 6: (continued)

Reference	Keywords	Main funding
Kim and Hong (2020)	Virtual exhibition; 3D environment; 2D environment; communication; enjoyment; virtual museum	The study compares the impact of 2D and 3D virtual exhibition presentations on visitor communication and enjoyment, finding that while 2D presentations are more effective for intuitive communication, 3D presentations encourage visitors to explore the virtual environment.
Pan and Luh (2020)	Visitors experience; parent-child group; experience measurement	The study investigates the experience of family groups visiting child-oriented exhibitions in local museums in China, utilizing qualitative research methods and analysis of online comments to develop a measurement framework for evaluating visitors' experience and enhancing the design of these exhibitions.
Kasemsarn, Harrison, and Nickpour (2023)	Digital storytelling, presentation, museum, youth, cultural tourism, guideline, audience	The study developed a digital storytelling presentation guideline for museums, integrating experts' and audiences' perspectives, to engage young tourists by proposing onsite and virtual presentations, as well as short presentations to attract prospective visitors.
Al-Taie et al. (2022)	Self-assessment mannequin	The study reveals the potential of customized soundscapes in virtual museum exhibits.
Meng, Chu, and Chiu (2023)	Covid-19; virtual museum; online exhibition; museum function; qualitative study; Hong Kong	The study highlights the expansion of online resources and virtual museums while emphasizing the need to balance user expectations with realistic practices.
Khakim and Sulistyo (2021)	Bojonegoro; history education; virtual museum	The study proposed the development of an android-based virtual museum application for Bojonegoro, addressing the limitations of physical museums and providing historical and cultural information to the community.

Table 6 presents a summary of the most representative articles characterized by the keywords associated with Cluster 3.

3.3.4 Cluster 4

This cluster focuses on immersive technologies such as augmented reality (Cao 2022) and virtual reality (Lo et al. 2019) in online museum design. It explores how these technologies can be used for educational purposes (Guo et al. 2023), user engagement (Dağ, Çavuşoğlu, and Durmaz 2023), creating virtual environments (Hsieh et al. 2022), motivating users to interact with online museums (Zotos et al. 2022), and understanding the role of play in digital cultural experiences (Sprugnoli et al. 2021). It also includes research on student engagement with online museums (Ekengren et al. 2021).

Table 7: Main results of articles whose keywords belong to cluster 4.

Reference	Keywords	Main funding
Cao (2022)	Mobile information systems, augmented reality	The study developed a virtual museum panorama roaming system for the Hubei Museum using Pano2VR, enhancing the cultural relics' research value and increasing user interaction through a more immersive online exhibition experience.
Lo et al. (2019)	Hong Kong; museums; virtual reality; Chinese martial arts; Hong Kong Heritage Museum; museum visitors	The article explored the use of 3D interactive media technologies to enhance visitors' experiences at an exhibition on Hakka Kungfu.
Zotos et al. (2022)	Three-dimensional displays; animals; behavioral sciences; virtual museums; wildlife; metadata; motion capture; motion detection	The article describes the design and development of a 3D virtual museum that incorporates high-resolution mesh reconstructions of reptiles, captures their movements, and provides interactive online functionalities through virtual reality and augmented reality, aiming to educate the public about animals and preserve wildlife.

Table 7: (continued)

Reference	Keywords	Main funding
Hsieh et al. (2022)	Eye tracking; fixation; sequence analysis; eye movement	The study conducted a study on museum visitors' visual cognition, finding that visitors' interest in displayed content positively correlates with cognitive performance and emphasizing the significance of eye movement and fixation as indicators for effective exhibition design, with implications for integrating virtual environments to enhance cognitive information, such as in augmented reality (AR), virtual reality (VR), or metaverse environments.
Cheng (2021)	Virtual reality; museum; partial least squares; presence; situational interest	The study explores the relationships between spatial presence, situational interest, and behavioral attitudes in online virtual museums.
Dağ, Çavuşoğlu, and Durmaz (2023)	Augmented reality; immersive experience; place satisfaction; user engagement; perceived authenticity	The study identifies the positive effects of augmented reality on immersive experiences in museums.
Su et al. (2022)	Digital archive system; color characterization model; imperial silk robe; "Qianlong Palette" color chart; color image reproduction	The study developed the color image reproduction system of a digital archive for imperial Chinese robes in the Qing Dynasty.
Massarani, Del Vecchio, and Degl'Innocenti (2021)	Science museums; science communication; non-formal education; public engagement in science; protagonism; agency	The study emphasizes the significance of explainers' mediation in children's engagement with interactive exhibits.
Elvekrok and Gulbrandsøy (2022)	Senses; positive memory; tourism; experience design; sensory profile	The study underscores the critical role of sensory stimulation in enhancing positive memories and overall experience evaluation in museum settings, as demonstrated through a field study conducted in two museums.
Raptis, Kavvetsos, and Katsini (2021)	Human-computer interaction; multimodal interactions; eye tracking; voice; cultural heritage; museum; artificial intelligence	The paper presents the design and evaluation of an interactive system, called MuMIA, that employs multimodal interfaces to enhance visitor experiences and understanding of art contexts in cultural heritage environments, highlighting the role of natural human-computer interaction and the intersection between human-computer interaction and artificial intelligence in this domain.
Magliacani and Sorrentino (2022)	Value co-creation; higher-education; service design; engagement; heritage	The study proposes a conceptual model that differentiates between synchronous and asynchronous value co-creation practices, offering insights into managing museums' co-creation practices virtually.
Ekengren et al. (2021)	3D collections; digital archaeology; 3D web visualization; higher education; Covid-19 pandemic	The study introduced the dynamic collections project which explores the use of 3D web infrastructure to support higher education and research in archaeology. The project examines how students engage with archaeological collections in a digital environment and presents preliminary results of online teaching experimentation during the Covid-19 pandemic.
Guo et al. (2023)	VR technology; virtual scenes; revolutionary education; visual experience	The study demonstrates how virtual reality technology can be effectively integrated with museum artifacts and intangible cultural assets to design immersive virtual scenes for revolutionary education, thereby expanding online access to such educational experiences.
Lee et al. (2021)	Augmented reality; museum exhibition; educational content; primary school children; blended learning	The study created online and offline experiential augmented reality (AR) learning tools, demonstrating enhanced learning experiences and appreciation of cultural and historical assets among elementary school students.
Ekengren et al. (2021)	3D collections; digital archaeology; 3D web visualization; higher education; Covid-19 pandemic	The study introduced the dynamic collections project which explores the use of 3D web infrastructure to support archaeology education and research, with a focus on online teaching during the Covid-19 pandemic.

Table 7: (continued)

Reference	Keywords	Main funding
Liritzis, Volonakis, and Vosinakis (2021)	Sanctuary of Delphi; virtual heritage; learning approach; higher education; virtual reality; unity 3D	The study demonstrated that the use of 3D reconstruction technology in the cultural heritage domain, specifically at the Sanctuary of Delphi, led to positive learning outcomes and enhanced interaction through an immersive 3D environment.

Table 8: Main results of articles whose keywords belong to cluster 5.

Reference	Keywords	Main funding
Huang and Ng (2021)	Reflection; serious games; internet of things; digital culture; museum	Internet of Things (IoT) serious games in museums effectively support cultural learning and reflection, and it provides design guidelines for future IoT-mediated interactive exhibits to enhance reflective learning experiences.
Nanetti, Radzi, and Benvenuti (2021)	Digital humanities; science; technology; engineering manuscripts; archival documents; world maps; engineering historical memory; 2D and 3D web-based reproductions; web-based learning tools for exhibition settings	The study focused on the development of web-based learning tools for accessing manuscript artifacts in exhibition settings, proposing solutions within the Engineering-Historical-Memory online interactive system.
Gharibi et al. (2022)	Physically disabled tourists; technology acceptance model; XR technology; virtual reality; augmented reality; heritage tourism; museums	The study explores the effects of extended reality (XR) technologies, including virtual reality (VR) and augmented reality (AR), on the behavioral intentions of physically disabled tourists using a modified Technology Acceptance Model (TAM).

A comprehensive summary of the key articles linked to the keywords in Cluster 4 is provided in Table 7.

3.3.5 Cluster 5

This cluster examines various aspects of technology adoption and user satisfaction (Dağ, Çavuşoğlu, and Durmaz 2023) in online museums. It includes research on internet-based technologies (Huang and Ng 2021), performance evaluation of online platforms (Nanetti, Radzi, and Benvenuti 2021), ensuring quality user experiences (Venigalla and Chimalakonda 2019), technology acceptance models (Gharibi et al. 2022), and user acceptance of online museum platforms.

Table 8 offers a detailed summary of the primary articles whose keywords are categorized within Cluster 5.

4 Discussion

The analyzed articles provide concrete answers regarding the use of immersive technologies and user engagement strategies in online museum design, particularly in the context of virtual reality, augmented reality, and digital heritage preservation. However, they fail to address specific aspects of visual communication, such as the use of color schemes, textures, icon design, typography, and overall website composition. While the studies emphasize technological innovations and user experiences, there is a noticeable gap in research on how visual elements like layout, font choices, and design consistency impact user engagement and satisfaction. Future research should focus on the role of these visual communication aspects in enhancing the aesthetic appeal and usability of online museum platforms.

This study has certain limitations that stem from the reliance on publication data solely from the Web of Science database. It is evident that for a more comprehensive overview of scientific research on the subject of design and technology in online museums, it is necessary to consider publications from other databases, particularly Scopus. The results also demonstrated that while the term “online museum” is accurate and widely used, the term “virtual museum” deserves attention as a basis for search queries in the database. This finding determines the direction of further research.

The text analysis also showed that the division into clusters can be arbitrary. This is due to the fact that one article can have keywords assigned to different clusters, as is seen with Dağ, Çavuşoğlu, and Durmaz (2023). On the other hand, some articles, such as that of Li, Nie, and Ye (2022), have only one keyword in the Web of Science database, so to assign an article to a certain cluster it is necessary to take into account the main findings of the article.

5 Conclusions

The analysis of the studies in the Web of Science database identified five clusters of research in the field of online

museum design. Cluster 1 focused on visitor behavior, Covid-19's impact on cultural institutions, design considerations, digital cultural heritage, online exhibitions, social media, travel, and website usability. Cluster 2 examined accessibility, bias, citizen science, conservation, higher education's role, museography, museology, museum participation, and sustainability. Cluster 3 explored authenticity, user experiences, virtual heritage, modeling, online platforms, virtual reality, and the intersection of technology, tourism, and virtual museums. Cluster 4 investigated immersive technologies, including augmented reality, virtual reality, education, user engagement, virtual environments, and play. Cluster 5 analyzed technology adoption, user satisfaction, internet-based technologies, platform performance, user experiences, technology acceptance models, and user acceptance. These clusters encompassed various aspects of online museum design, such as user experience, accessibility, technology, education, and cultural heritage. The systematic review provides valuable insights for researchers and practitioners, highlighting areas for further investigation and development in online museum design.

The findings offer valuable insights for museum professionals, researchers, and designers in optimizing online museum experiences, reaching diverse audiences, and utilizing innovative technologies to improve visitor engagement and satisfaction. By implementing these design principles and technological innovations, online museums can create enriching cultural experiences and foster a deeper appreciation for art, history, science, nature, textile, and cultural heritage.

Further research involves a review of publications using other scientific databases as well as using the term "virtual museum" for a wider coverage of publications in this direction.

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