Towards a Digital Shift in Museum Visiting Experience. Drafting the Research Agenda Between Academic Research and Practice of Museum Management

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Abstract This chapter reviews the state of the art in digital applications for museums and exhibitions, with a particular focus on the visiting experience. The authors have measured the gap between academic research and the current practice of museum management through a mixed-methodology approach. On one hand, the text presents the result of a systematic literature review of articles on museum digitalization that have been published since 2000. On the other hand, it includes the results of an interview with a group of experts, directors, and curators of Italian museums to understand the degree to which digitalization is currently adopted in those cultural institutions. COVID-19 is an additional factor that has been considered in terms of its impact on scientific production and museums' strategies. Such cultural institutions, having ticketing and similar forms of revenue related to physical visitors at the core of their model of economic sustainability, suddenly realized the need for a different approach to promoting art, namely forms of engagement from a distance. Within the frame of industry 4.0, it has become evident the crucial role experts play in the field of digitalization and implementation of virtual environments for the art sector. This text aims to draft a research agenda on museum digitalization for the near future, looking at trending topics, academic networks, and research geographies. The qualitative survey with experts' opinions discussed whether regular employment of digital platforms and virtual tours can engage new visitors in the long term, and established the current status of their day-to-day activities.

Keywords Survey · Literature Review · Digital Shift · Museum Sector · Digitalization

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United Nations' Sustainable Development Goals 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation · 10. Reduce inequality within and among countries · 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

1 Introduction

1.1 Outline

In the last twenty years, the digital shift in the field of art and architecture has been forming a new body of theory that encompasses: a revision of the design phase [1]; new manufacturing processes and robotic fabrication [2]; the adoption of intersectoral educational models [3]; and the introduction of virtual experiences in connection with or in replacement of existing spaces and heritage sites. The latter will be at the center of this analysis, with the intention to draft the research agenda for the museum sector facing such new paradigms as: digital twins, data-driven strategies, Virtual Reality and Augmented Reality, real-time digital representation, and visitor-computer interaction.

This chapter intends to review the status of digitalization in museums, with a particular focus on the visiting experience. In this regard, we have decided to measure the gap between academic research and the current practice of museum management. On one hand, the text presents the result of an extensive literature review of articles that have been published since the year 2000. On the other hand, the authors have conducted a semi-structured interview with a group of experts, directors, and curators of public museums to understand the degree to which digitalization is currently adopted in museums.

The digital shift in the museum visiting experience has been occurring for many decades. It started with the concept of museum computing at the end of the 1960s [4], firstly integrating archives and records and then affecting the visiting experience with the evolution of audio–video guides [5]. This text intends to lay out the updated state of the art for the issue of museum digitalization by studying the current research panorama together with trends of future strategic implementations.

Among the many impacts of COVID-19 restrictions in the last two years, the digitalization of the museum experience has secured the attention of many researchers [6, 7]. Cultural institutions devised multiple communication strategies and virtual environments to target visitors' engagement during this period. In this chapter, we will also examine how this affected the direction of academic research considering the output published since 2020, when restrictions were enforced. Simultaneously, if we are to draft a research agenda for the near future, we should be able to contextualize the pandemic event as a prominent but circumscribed occurrence. Hence, it is vital

to step back to a more comprehensive vantage point from which it is possible to trace the whole trajectory of museum digitalization in academia and practice.

1.2　Theoretical Framework: Interaction and visitor's Experience

Interaction in visitors' experience is usually addressed as synonymous with digital environments. Though, as pointed out by Levent and Pascual-Leone [8], sensory engagement and immersive experience can be obtained by triggering senses of smell, touch, sound, space, and memory in exhibition spaces. In this regard, Classen [9] has discussed how museums are essentially focused on the visual experience, while many masterpieces and historical artworks are intertwined with the overall bodily experience that the subject perceives. Hence, this aspect is essential to the visitor's feeling of being present in the venue and will be addressed throughout the expert interviews presented in this study. Additionally, the act of art appraisal by visitors is mediated through a behavioral code established by the institution (i.e., museum, gallery, collector), and it is not always clear how the author intended their work to be experienced in the first place. For example, if touch and manipulation are allowed, and to what degree [10]. In archaeological museums, such impasse has been solved with partial or integral 3D printed replicas of the original that would satisfy the necessity of object handling as an exploratory phase of the visit [11].

Interaction aims then at increasing the level of engagement with the subject, mainly to produce long-term involvement [12]. In this sense, engagement as "the willingness to have emotions, affect and thoughts directed towards and aroused by the mediated activity in order to achieve a specific objective" [13] would be the ultimate goal of professionals working in the field of culture.

Societies have always constructed alternative worlds to engage an audience of visitors, religious believers, gamers, etc., projecting to another environment activities or representations that the physical world couldn't afford [14]. In museums, the traditional visit can be augmented with a narrative structure (storytelling), additional content (multimedia), and immersive experience (virtual reconstructions). Bekele and Champion [15] compared virtual reality technologies in virtual heritage, examining the most used interaction interfaces: Augmented Reality (AR), Virtual Reality (VR), Augmented Virtuality (AV), and Mixed Reality (MxR). The latter is seen as the most viable option for heritage sites and museums to establish a relationship between users, virtuality, and reality, without losing the social dimension of cultural learning. In fact, the educational value of museums is seen as a primary form of interaction [16], both within and outside 3D virtual environments [17].

This bond between century-old institutions and digital interactive tools opens another issue we will address through the expert interviews: the digital preparedness of museums. Hanussek discussed the supposed enhancement of the visiting experience through ad-hoc smartphone applications, pointing out that "museum apps have

not brought the impact so often promised to visiting audiences" because "professional expertise in information technology and data analysis seem still to pose a huge challenge for museums, as evidenced by the technical issues of the discussed apps and the lack of proper assessment of their user experiences" [18]. Hence, we have asked the interviewed experts to describe the consistency of the information technology personnel in their institutions, if any.

Engagement also has an online phase that is conducted on social media channels. In relation to the visit, digital content can help build the construct of the visitor's motivation before the visit, or complement the acquired information after the visit [6]. We have addressed this issue in the bibliographic review and with specific questions to the experts. It should be noted that COVID-19 restrictions have impeded physical visits, offering for a certain period a unique opportunity to measure the delivery of cultural content through online platforms only [7]. This raised the question of the degree of replaceability of online experience in opposition to onsite presence. The use of digitization and social media also has profound political implications because it is being directed by choices that imply a selection ex-ante, and received on devices that are subject to digital divide disparities [19]. Hence, authority and curation of content are not secondary to the impact on visitors' experience through social media. In turn, different platforms have different audiences, making the overall assessment fragmented by definition: while Twitter has stronger involvement with political and social issues [20], Instagram's feed is predominantly visual and has more aesthetic connections with the experience of an exhibition [21]. Contents on Facebook create virtual communities of users interested in a specific topic: it allows interaction in both directions, but at the same time users expect the cultural institution to be consistently responsive to maintain an effective engagement [22]. The creation of content is then tailored to the specific platform if museums intend to gain maximum engagement, requiring an effort in communication strategies that is constant and with a long-term perspective.

Online communication covers a broad spectrum of channels, from institutional websites to chatbots. The former is unidirectional and aimed at a generic prospective visitor; the latter is "a computer program designed to simulate conversation with human users" [23] with one-to-one interaction.

Finally, the visitor's experience can be considered interactive when the museum activates participatory projects of co-creation. This social aspect has an extensive literature and is widely studied among practitioners and researchers [24–27]. We will address it several times in the bibliographic collection and with the questionnaire only in relation to the digitalization of the visitor's experience.

This study builds upon an article on the impact of virtual tours on museum exhibitions that we have recently published [6]. We have decided to define the perimeter of the investigation through the following parameters:

- Definition of a specific setting: museum. Art galleries, fairs, temporary exhibitions, and art parks are not taken into consideration.
- Definition of a specific subject: visit. Laboratories, archives, museum libraries, happenings, and talks are not taken into consideration.

- Definition of a specific aspect of the visitor's experience: digitalization.

Other literature reviews partially cover these three elements, but none is updated, with a systematic approach, or contains all the aforementioned components. Xu et al. [28] analyzed research results published between 2011 and 2021 on the impact of technology applications on museum learning outcomes retrieved from the core Web of Science collection. Ayala et al. [29] examined research articles on audience development in museums and heritage organizations, combining results from three different databases. Serravalle et al. [30] focused their attention on research items on augmented reality in the museum with reference to the pool of stakeholders.

2 Literature Review

2.1 Methodology

This bibliometric analysis is structured in two components that will be addressed separately in the result section. One concerns descriptive metrics in the domain of museum digitalization in terms of overall scientific production and its yearly evolution. The second looks at knowledge structures across the pool of articles considered for this research.

To collect a reliable and representative number of articles, papers were retrieved from the core Web of Science collection, containing journals in the Science Citation Index Expanded and Social Sciences Citation Index.

Bibliometrix R-package and Microsoft Excel were used for analysis. Bibliometrix is a science mapping open-source tool programmed in R that elaborates research distribution, subjects, and citations [31]. The following objectives have guided this quantitative analysis:

- Establish ground for comparative evaluation with expert interviews
- Identify research trends and specific geographies interested in the topic of museum digitalization
- Visualize the collaborative network that shares an interest in the topic of museum digitalization
- Study the use of keywords in scientific production
- Identify the most cited articles, journals, and authors.

Articles had to contain the three components that form the construct of this research: keywords "visitor", or "visit", or "engagement"; and keywords "digital" or starting with "digitali"; and keywords "museum", or "exhibition". With the Boolean operators "AND NOT" we have excluded those articles that contain the keyword "archive" as it is within the domain of museum studies but beyond the scope of our study on the visitor's experience; and the keywords "machine learning", "deep learning", or "artificial intelligence", that characterize articles beyond the scope of our study. The analysis was conducted in March–April 2022, and the records are

Table 1 WoS search query

Search syntax
Visitor OR visit OR engagement (All Fields)
AND digitali* OR digital (All Fields)
AND museum OR museums OR exhibition OR exhibitions (All Fields)
AND NOT "machine learning" OR "deep learning" OR "artificial intelligence" (All Fields)
AND NOT archive (All Fields)
AND 2022 or 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 or 2007 or 2006 or 2005 or 2004 or 2003 or 2002 or 2001 or 2000 (Publication Years)

updated to April 22nd. We have included all articles published in the last 22 years, considering that 2022 is represented only for the first four months of the year and will have limited relevance in certain aspects of the result section. A total of 1257 results were obtained with the syntax shown in Table 1.

After removing duplicates, 1240 articles were left. Then a close reading of titles and abstracts reduced the number to 1109, considering articles whose content is not covering any issue related to museums, visitor engagement, or virtual reality. We reported that some research published in journals of environmental sciences, ecology, and zoology, contain the same key terms but address very different research fields. Finally, after discarding reviews, editorials, data papers, and meeting abstracts, the pool of items reached the final number of 1082.

3 Results and Discussion

Overview. Articles are spread across 675 sources (books, journals, proceedings) with an average number of citations per document of 4.43, and 0.72 average citations per year per document. Items are mainly journal articles (54%) and conference papers (42%), and only 4% are published as book chapters. The total of authors involved is 2886, meaning 0.38 documents per author and 2.67 authors per document. Multi-authored items are 850 (79%), with 3.2 co-authors per document and a Collaboration Index (CI) of 3.13. The latter measures the mean number of authors of multi-authored papers per joint paper [32, 33], while co-authors per document measures authors' appearances per total number of documents. This suggests that the research team is generally formed of three authors. In terms of annual scientific production (Fig. 1), starting from 2016, publications constantly total 100 or more. The graph shows a considerable jump in 2018, maybe because the hardware for immersive reality started to become affordable and adopted by major entertainment companies [34]. Another spike is positioned between 2020 and 2021, when COVID-19 restrictions have amplified the debate on digitalization of cultural institutions. Compound Annual Growth Rate returns a constant rate of 14.59% over the examined period. Considering

the average article citation per year (Fig. 2), articles that collect the highest number of yearly citations were published in 2000 and 2008.

It should be noted that we will differentiate between global citations, those that are provided by WoS metrics gauging the impact of an article in the whole database and across all disciplines, and local citations, those that are received from documents that are present in the analyzed collection as is formed through the search query in Table 1. Hence, the latter measure the impact in the field of museum digitalization.
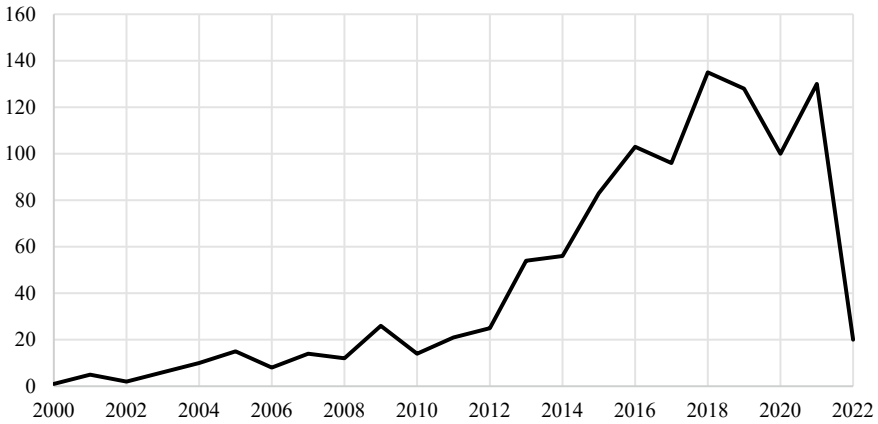

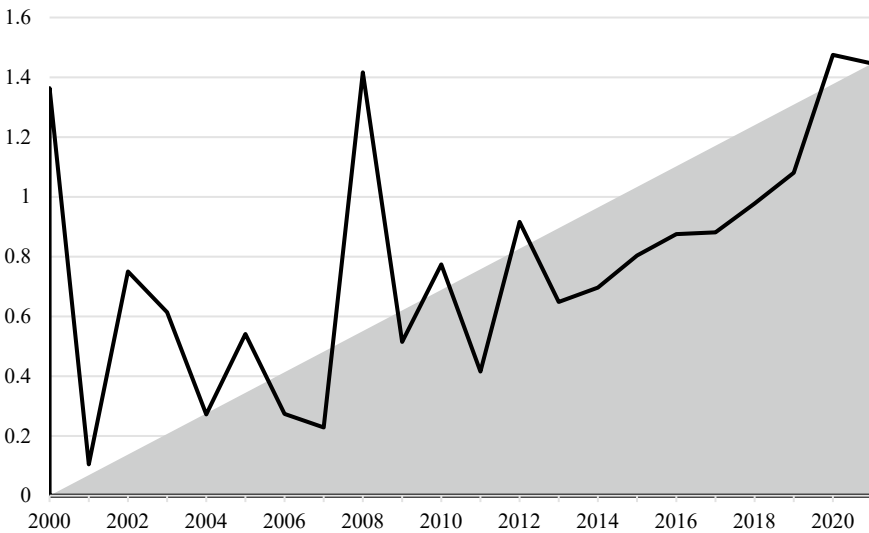**Fig. 1** Annual Scientific production. Y: Articles, X: year

Fig. 2 Average Article Citation per Year. Y: Citations, X: year

Analytics and graphs. The analysis covers statistics on sources, authors, and documents. First, we examine the relationship between topics and geographies by looking at the keywords of the academic works.

Examination of keywords (Fig. 3) shows that the authors' countries are mainly the United Kingdom (237), Italy (229), Greece (101), Spain (101), and the USA (90). The keyword "cultural heritage" is mostly used by Italian authors. British scholars prevail in the use of "digital heritage". Keywords "virtual reality" and "augmented reality" have a similar distribution; the former is used by most of the Austrian and Chinese authors that were considered in this research; British authors mostly address "engagement"; "social media" and "virtual museum" are frequently cited by Italian authors; "education" is the second most used keyword by Spanish scholars. If we look at the authors' affiliations (Fig. 4), "cultural heritage" is mainly used by authors from Sheffield Hallam University and Università Politecnica delle Marche. The former prevails in the use of "virtual reality", the second in the use of "augmented reality". Some keywords are almost exclusively linked to one university: "social media" to Politecnico di Milano, "engagement" to King's College London, and "heritage" to Newcastle University. Vice versa, certain universities are very much focused on specific topics: the University of Peloponnese on "cultural heritage" and the University of Patras more generally on "museums", which is part of the search query, and is not linked to any of the top 20 keywords. The University of the Aegean and the University of Nottingham distribute their contributions in most of the top 20 keywords.
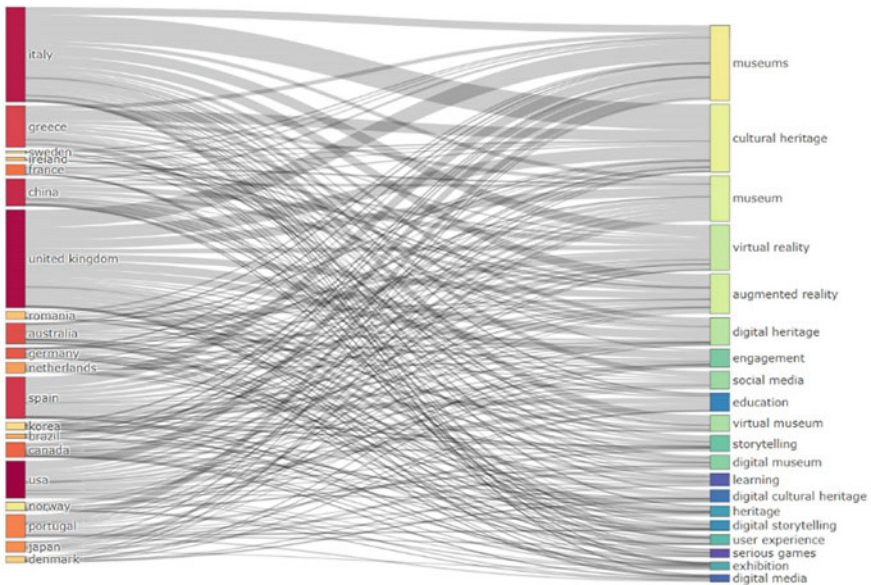

Fig. 3 Fields plot elaborated by Bibliometrix. Left column: author's country, right column: keywords
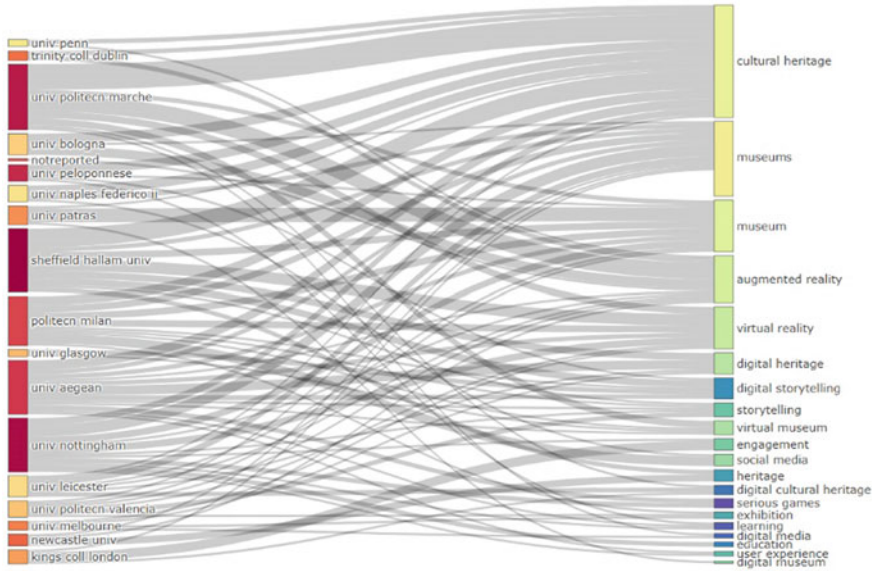
Fig. 4 Fields plot elaborated by Bibliometrix. Left column: author's affiliation, right column: keywords

It should be considered that the keywords mentioned above are the author's keywords. Although many publications suggest a preference for using Keywords Plus [35, 36], which are index terms generated by an algorithm that scans the titles of an article's bibliography [37], they are usually more generic and linked to methodological aspects [38]. For this reason, we will employ Keywords Plus to better understand the structure of scientific production on museum digitalization, while author keywords are considered better descriptors of the content of the articles [20, 38].

The journal Museum Management and Curatorship (Humanities, AHCI), providing 31 documents, is the most relevant source in terms of published articles. Second is the ACM Journal on Computing and Cultural Heritage (Computer Science and Humanities, SCIE, and AHCI), with 25 articles. The journal of Museum Education (Education & Educational Research, ESCI) with 14 articles, and Curator – The Museum Journal (Humanities, AHCI) follow. Particularly relevant are the two volumes of the 2015 Digital Heritage International Congress, with a total of 34 contributions pertinent to the subject. The congress held in Granada, Spain, is then the venue where museum digitalization has been more organically discussed in the last 22 years. The following 2018 Digital Heritage International Congress held in San Francisco, California, is well represented with 12 papers. Source clustering through Bradford's law [39, 40] shows that the core area that represents the nucleus of journals that cover the examined issue is quite broad. Bradford's model suggests that the core

literature is scattered across 41 periodicals, confirming that the issue of museum digitalization is highly interdisciplinary and is present in sources of different scientific fields.

To evaluate sources' impact, we have considered the *g-index* developed by Egghe, which is the "unique largest number such that the top g articles received (together) at least g^2 citations" [41]. It has been demonstrated that this index, compared to the *h-index*, is not influenced by the total number of publications [42]. Hence, in our case is preferable because the initial publication year varies considerably. Museum Management and Curatorship has the highest *g-index* (17), and ACM Journal on Computing and Cultural Heritage is second with 12. Considering the number of examined articles, those published in Digital Creativity (g = 8) and in Visitor Studies (g = 6) have had a significant impact. Of the 12 top journals with a *g-index* of 5 or above, 5 are published in England, 3 in the USA, 1 in Greece, 1 in Italy, 1 in Poland, and 1 in the Netherlands. The category of humanities is the most represented with 6 periodicals, then computer science and archaeology with 3, art with 1, tourism with 1, and social sciences with 1. Most are indexed in AHCI collection (8), SCIE (3), ESCI (2), and SSCI (1). Source dynamics performed on these journals (Fig. 5) shows that periodicals concerned with museum studies have constantly investigated museum digitalization starting from the period 2004–2008, while periodicals more centered on computer science have considerably increased their interest only in the last years.
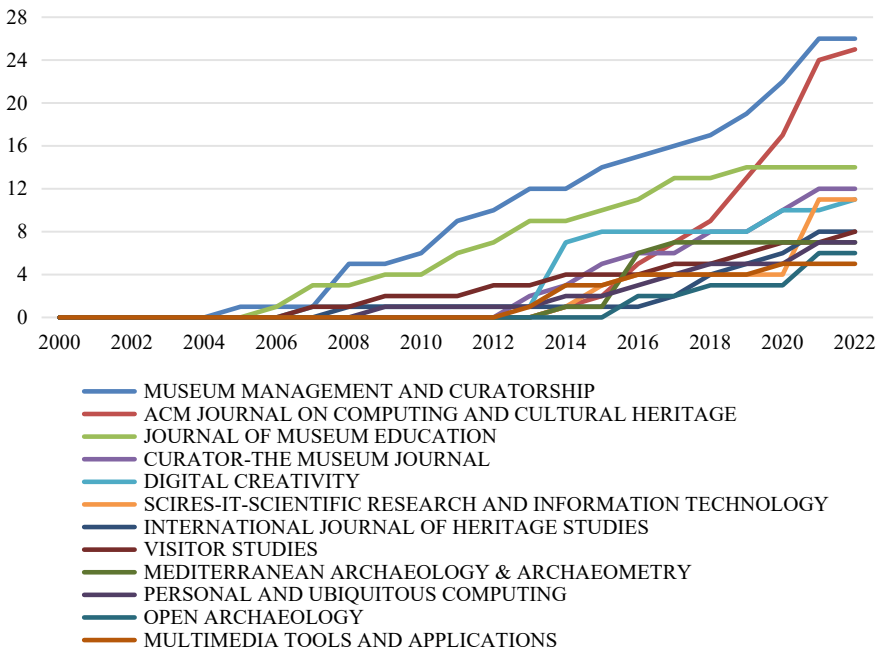

Fig. 5 Source dynamics. Y: Cumulate publications, X: year

Focusing data analysis on authors, we observe that the top-ten most relevant authors per fractionalized number of documents [43] range from 0.8 to 4.4 documents. Top-ten authors per fully counted documents, ranging from 6 to 11 papers, are the same as the fractionalized count with slight differences in terms of rank. Benford has the most extended production on the subject over time, while Antoniou has the most protracted timeline if we consider active authors that have already published an article in 2022. Petrelli has constantly published every year 1 to 4 articles from 2016 to 2020, and Lepouras has continuously published 1 to 4 articles from 2016 to 2019. COVID-19 is having a remarkable impact on authors' production on museum digitalization: the two most cited articles were published only in 2020 and 2021 by Arnaboldi and Agostino (joined by different co-authors) with the titles "New development: COVID-19 as an accelerator of digital transformation in public service delivery" [44] and "Italian state museums during the COVID-19 crisis: from onsite closure to online openness" [7]. Both look at how Italian state museums implemented strategies of engagement during the lockdown. This element confirms that researchers have shifted their focus in the last three years. Another interesting aspect is that most of top authors' timelines start in 2013–14 and end in 2020, suggesting that 2021 imposed a halt in terms of production. Top authors published the majority of their articles in 2017–18.

Frequency distribution of scientific productivity studied with Lotka's Law [45] shows that 88% of items are authored by occasional contributors, while core authors have published at least 5 articles on the topic. The 0.2%, 19 researchers, can be considered core contributors in the field. Rounding this number to the 20 top authors, their *g-index* ranges from 4 to 9, with Petrelli and Pierdicca that record the best local impact.

The most relevant affiliations per number of articles are Sheffield Hallam University (25), University of Nottingham (21), Università Politecnica delle Marche (20), University of Peloponnese (16), University of the Aegean (13), Politecnico di Milano (12).

In Fig. 6, we can see the corresponding author's geographical distribution. Almost the same number of articles have Italian or UK corresponding authors, followed by USA, Chinese, and Spanish researchers. The total is then split into Single Country Publications (SCP), which are co-authored by researchers of the same country, and Multiple Countries Publications (MCP), with at least one co-author from a different country. Hence, the MCP ratio measures the intensity of international collaboration of a country. In this regard, the Netherlands (44%), Sweden (33%), and Denmark (29%), have the best ratio of international collaboration. Low international collaboration is measured with Brazilian, Romanian, Japanese, and French authors.

Counting instead the number of documents per country (Fig. 7), namely the affiliation countries' frequency distribution, the USA is represented in 518 documents, the UK in 366, Italy in 285, and China in 144. Large parts of Africa and central Asia are not present in any affiliation. Though, in terms of total citations per country, UK authors collect a total of 936, prevailing on the USA with 759, Italy with 672, and after that is a considerable gap to the fourth, China, with 347 citations.
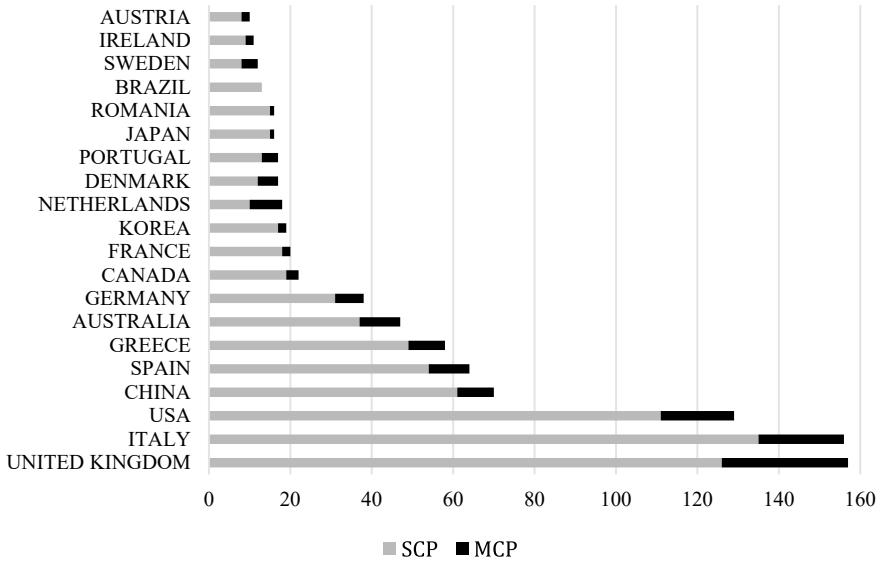
Fig. 6 Corresponding Author's Country. Y: number of publications (SCP = Single Country Publications; MCP = Multiple Countries Publications), X: country

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Fig. 7 Country scientific production. Scale: white (unrepresented countries) to dark grey (USA = 518)

The last aspect of our analysis is related to the 1082 items retrieved with the search syntax mentioned above. We will call "documents" all items that are included in the bibliographic collection; "references" all articles that are cited in the bibliography of each document; "cited documents" all articles that are included in the bibliographic collection and at the same time cited as references.

Within the examined bibliographic collection, the most locally cited source is the book series Lecture Notes in Computer Science, published by Springer with 340 citations. Curator (247), Museum Management and Curatorship (234), and Journal of Cultural Heritage (215) score a similar number of citations. Thesis works are also quite present, with 185 citations. The most cited author in museum digitalization is Petrelli (25 local citations), which is not surprising as her works are all centered on the relationship between museums and digital platforms. Marty has 18 local citations, Not has 13 local citations (she co-authored three works with Petrelli), Agostino and Arnaboldi both have 12 local citations, having also co-authored three works together.

Most globally cited documents are published in computer science journals: "Using augmented reality and knowledge-building scaffolds to improve learning in a science museum" [46] 108 citations, "Effects of the inquiry-based mobile learning model on the cognitive load and learning achievement of students" [47] 78 citations, "Leveraging explicitly disclosed location information to understand tourist dynamics: a case study" [48] 75 citations. All three address museum issues only partially. This is demonstrated by the fact that top cited local documents are instead all published by Museum Management and Curatorship and are centered on museum issues: "Museum websites and museum visitors: digital museum resources and their use" [49] has 16 local citations, "The presence of Web 2.0 tools on museum websites: a comparative study between England, France, Spain, Italy, and the USA" [50] has 9 local citations, "Heritage in lockdown: digital provision of memory institutions in the UK and US of America during the COVID-19 pandemic" has 7 local citations. Their local/global citation ratio is 25% to 28%, meaning that more than one-fourth of their citations fall into the examined topic-specific bibliographic collection.

Concerning the most locally cited references, it is interesting to observe that although the majority of sources are journal articles, among the first 8 documents, only two are articles. The most cited source is Nina Simon's "The Participatory Museum" (53 local citations), which tackles the issue of community engagement through the design and practice of participatory projects. In fact, the author looks at the institution of the museum from a social point of view, examining the hiatus that the audience feels in terms of authority and relevance to their life [25]. John Howard Falk's books are second ("Learning from museums: visitor experiences and the making of meaning", 43 local citations), fourth ("Identity and the Museum Visitor Experience", 33 local citations), and eighth ("The Museum Experience", 20 local citations). The former [16] interprets museums as learning environments proposing a model underpinned by theories from psychology, education, anthropology, and neuroscience. The second [51] has a similar approach, focusing on the construct of visitors' motivations influenced by their identity. And suggests that some of these motivations occur even before a visitor enters the museum. The third [52] can be considered as the starting point of Falks' research, in collaboration with Lynn Diane Dierking, where the framework of the interactive experience is studied in its physical, personal, and social dimensions. All three books combine accessible language with broad multidisciplinary contributions. Similarly, the book "Learning in the Museum" [53], published by George E. Hein in 1998 (23 local citations), has a foundational role in laying out how the educational theories of John Dewey, Jean Piaget, and

Lev Vygotsky can be adapted to museum contexts. Tallon and Walker's edited book "Digital technologies and the museum experience: handheld guides and other media" [5] is the most cited document (25) that explicitly addresses the digital in its title.

The most cited articles are "Beyond virtual museums: Experiencing immersive virtual reality in real museums" (35 local citations), which examines the positive and negative aspects of immersive VR [54], and "Virtual museums, a survey and some issues for consideration" (26 local citations), on preservation and dissemination of cultural heritage through Web3D, VR, AR, MR, haptics and handheld devices, in a virtual museum environment [55]. Both are published in the Journal of Cultural Heritage.

In terms of the year of publication, references range from 1709 to 2022. Reference Year Publication Spectroscopy (RYPS) is a quantitative method that identifies the temporal roots of research fields, and is based on the analysis of the distribution of frequencies with which references are cited [56]. The RYPS of the studied bibliographic collection (Fig. 8) shows that the historical papers relevant to the field are quite recent, mainly published in 2012–14. The deviation curve shows only one distinct peak in 2010, when Simon [25] and Parry (ed.) [57] published their books, while Carrozzino [54] and Bruno [58] published their articles on virtual reality in the Journal of Cultural Heritage. Particularly relevant is 2012–13, when the personalization of visitor's experience has been widely discussed for the first time in separate articles by Ardissono [59], Lombardo [60], Capriotti [61], Charitonos [62], and Fletcher [63]. Also, Petrelli [64] and Coenen [65] discussed tools and applications for interactive visits. Additionally, the proceedings of the SIGCHI Conference on Human Factors in Computing Systems (2013) and the updated version of Falk and Dierking's book [66] contributed significantly. Other relevant historical references are published in 2004–5 and 2000–1.

The most relevant word in the bibliographic collection (Fig. 9), after having excluded the words used in the search query, is "heritage" among Keywords Plus occurrences (44) and "cultural heritage" among author's keywords (96). Both with
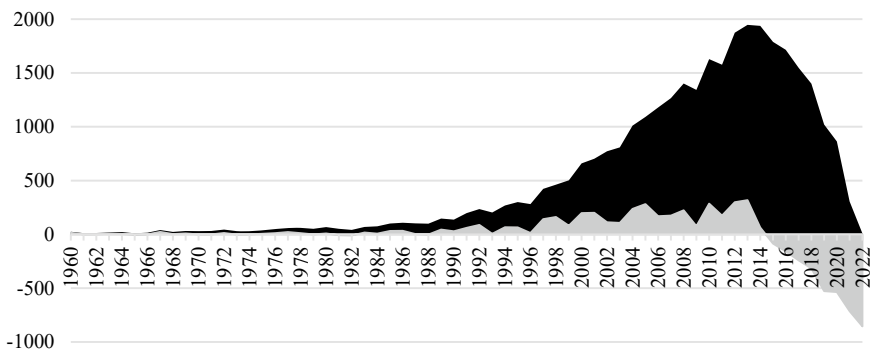

Fig. 8 Reference Year Publication Spectroscopy. Black: Number of cited references per year, Grey: Deviation from the 5-year median
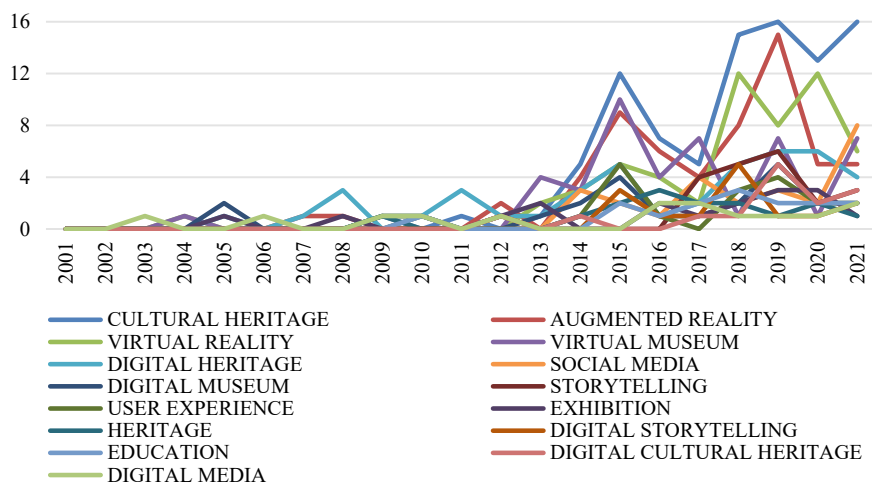
Fig. 9 Word dynamics. Y: Annual occurrence of author's keyword, X: year

a considerable gap on the second most used keyword. The frequency of "design" and "model" in Keyword Plus suggests recurrent works on methodological aspects. Author's keywords are very much referred to immersive reality ("augmented reality" and "virtual reality"). Abstract's words confirm the use of bigrams "cultural heritage" (297), "social media" (134), and "augmented reality" (126).

Over the years, starting from 2015, "cultural heritage" has been the most used keyword by authors (Fig. 9). Words that contain "virtual" ("virtual reality, "augmented reality", "virtual museum") also started to be used consistently in 2015. While words like "digital media" are being used from 2000, "storytelling" in association with the museum has been used only from 2017. The term "social media" shows the highest growth in 2021.

If we group frequencies of n words year by year, it is possible to know how trend topics vary within the examined collection. Searching the $n = 5$ most frequent author's keywords, "new media" and "website" were used until 2012. Then in 2012–16 gamification was introduced in several articles ("game-based learning", "3D modeling" and "usability") together with the concepts of "virtual heritage" and "participation". In 2016–19, "virtual reality" and "augmented reality" are the most studied topics together with the concept of "digital heritage". In 2019, there is a meaningful shift towards "storytelling" and "social media" until 2020–21, which shows another significant linguistic shift in terms of processes ("digitization", "digital culture" and "digital transformation"), tools ("3D printing"), social engagement ("museum education"), and events ("Covid-19"). The word "guide", which records frequent usage in many articles until 2014, is not frequently employed after 2016.

The words used in abstracts have similar dynamics, with an evident prevalence in the last three years of the words "eco museum", "HBIM", and "olfactory".

Trends essentially confirm a growing interest in visitor engagement in both social and technological acceptation, together with studies on social media. COVID-19 dramatically impacted titles and keywords, though it should be considered what will be the long-lasting effect of this event over time. The increasing use of "touch" and "olfactory" suggests that the visitor's experience is being studied beyond its visual dimension.

Structure of knowledge. The analysis outlines a conceptual, intellectual, and social structure of the research field. The visualization of this knowledge domain is expected to reveal the main themes and trends of the bibliographic collection, how certain authors influence the overall scientific production, and the geography of the research network [67].

Cluster map by documents coupling divides the items into subsets that are internally homogeneous and externally homogeneous. Figure 10 represents the five clusters positioned according to their impact and centrality (relevance to the field). This cluster analysis selects the top 250 documents with a minimum of 10% cluster frequency. Coupling is measured by references and the articles' impact through local citation score. The figure shows 5 clusters labeled with the main Keywords Plus terms: orange, blue, red, purple, and green.

The largest cluster (purple) is in the upper-right quadrant, with impactful and relevant documents. It has an impact of 2.62, a centrality of 0.42, and 82 documents. Marty [49] and Lopez [50] are the main contributors with research documents on museum websites and the use of web 2.0 tools. In general, articles in the purple cluster discuss how internet enhances the experience of a museum visit.

The green cluster is across the two right quadrants, with the highest centrality (0.43), average impact (2.28), and 57 documents. Smith [68] and King [69] are prominent authors in this cluster centered on social engagement with virtual environments and social media. Smith combines principles from participatory design with

Clusters by Documents Coupling

internet - conf 71.4%
experience - conf 27.3%
museums - conf 30%

cultural-heritage - conf 41.7%
design - conf 45.5%
museum - conf 33.3%

engagement - conf 41.7%
social media - conf 55.6%
experiences - conf 80%

reality - conf 87.5%
heritage - conf 50%
augmented reality - conf 66.7%

engagement - conf 33.3%
knowledge - conf 66.7%
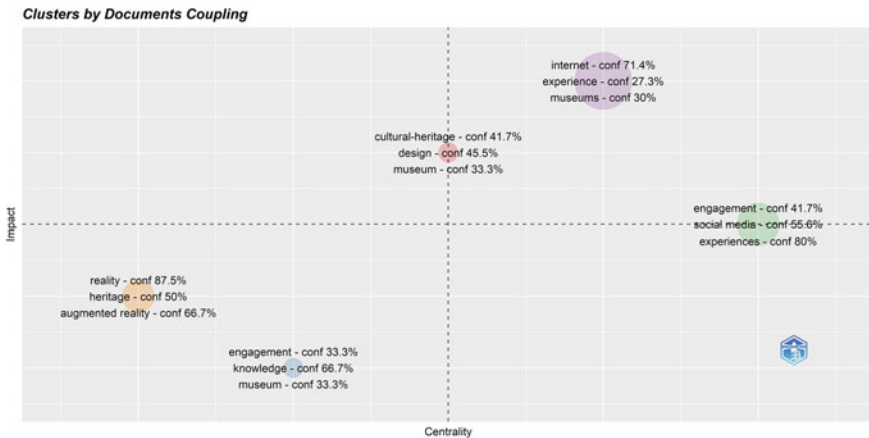museum - conf 33.3%

Impact

Centrality

Fig. 10 Clusters by documents coupling positioned by impact and centrality. For color interpretation, refer to the text

themes of contemporary digital culture to create heritage innovation; King analyzes literature on digital engagement, interactivity, and participation in combination with a survey of heritage professionals.

The red cluster is across upper quadrants, with average centrality (0.41), relevant impact (2.45), and 33 documents. Most contributions are published in computer science journals and provide case studies of interactive exhibitions for cultural heritage. Among authors, Pierdicca [70] suggests the implementation of the Internet of Things framework to study visit patterns for a personalized museum experience, while Petrelli [71] explores the design, implementation, use, and evaluation of tangible data souvenirs for interactive museum exhibitions.

The lower-left quadrat has two clusters with lower impact and lower centrality, suggesting topics that might be emerging or ending in the context of museum digitalization. The orange cluster is mainly represented with the keywords "reality" and "augmented reality", suggesting a focus on interaction interfaces: Augmented Reality (AR), Virtual Reality (VR), Augmented Virtuality (AV), and Mixed Reality (MxR). Orange has a centrality of 0.31, an impact of 2.1, and 45 documents. Barsanti [72] discusses the optimization of 3D models of artifacts for virtual reality, Yoon [46] studies informal learning in a science museum using augmented reality, and Caggianese [73] analyzes interaction design focusing on a holographic projection system equipped with a gesture-based interface. The blue cluster has a similar focus on interaction interfaces but is more directed toward the learning impact rather than the design implications addressed in the orange cluster. Blue cluster has a centrality of 0.39, impact of 1.90, and 33 documents. One representative article is the study by Damala [74] with a qualitative and quantitative analysis of an augmented reality prototype to achieve an interactive learning experience in museums.

Moving to the visualization of the conceptual structure, Fig. 11 represents the co-occurrence network of authors' keywords. The network is based on simple similarities between words that are hierarchically grouped in clusters. After removing the words of the search query, we can see the core cluster, in red, which is formed around the concept of digital heritage and the use of VR and AR. Associated with these, we see other tools such as 3D printing and mobile applications, forms of visit augmentation such as storytelling and gamification, and hybrid approaches such as mixed reality.

Most of the terms are strongly connected with the center of the blue cluster that revolves around the virtual museum as a setting for the exhibition. Satellite words refer to 3D reconstruction, virtual heritage, and the issue of digitization itself.

The green cluster is isolated but internally coherent with the topic of social media. The terms "communication", "participation", "education", and "digital culture" complete the cluster together with "covid-19". The latter is also the only connection of this cluster with "virtual museum". This result confirms that the impact of the pandemic has been primarily studied in connection with the social media activity of museums.

The purple cluster is centered on the user experience and has stronger ties with the red and blue clusters. The words refer to the visitor's perspective, and especially to interaction design and personalization. Finally, the isolated yellow cluster suggests an interest in informal learning through games.

Fig. 11 Co-occurrence network of author's keywords. Elaborated by Bibliometrix

The thematic map of authors' keywords (Fig. 12) visualizes four types of themes based on two dimensions: centrality (importance of the topic in the given research field) and density (level of development of the theme). The motor themes of the discipline are based on aspects of communication, education, and visitor experience. Basic and transversal themes relate to cultural heritage on the one hand, and virtual museum (with augmented reality) on the other. Blue cluster on social media and COVID-19 is being consistently developed together with another cluster that contains digital humanities and technology. Two clusters are in the quadrant of niche themes, namely highly developed and isolated topics. One is virtual archaeology; the other refers to informal learning through gaming applications.

Two clusters collect themes that are less developed. The orange cluster with "digital storytelling" and learning scenarios is also in the field of basic themes. Instead, the purple cluster containing "survey", "co-design", and "community engagement" is peripheral to the research field, suggesting that it is possibly emerging or declining.

When the thematic map is evaluated over time, it draws a trajectory of the evolution of the topics, and how they are developed and connected together. In order to set the time span of each period, Fig. 1 shows that 2012 and 2017 are two crucial turning points in scientific production. Hence, time slices are set accordingly, weighting occurrences of 250 words year by year.

Figure 13 shows that in the first sub-period, museum digitalization is dominated by discussions around the virtual museum and digital media, mainly supported by research on augmented reality and interaction design. Starting in 2013, the virtual museum concept grows and assimilates issues related to digital media and digital heritage. In the second sub-period, topics are much more specialized and introduce a social aspect in the field: social media, education, children, and storytelling. The last period is short but characterized by massive scientific production. Most of the technological issues investigated in 2013–17 (augmented reality, 3D printing, gamification, user experience), converge to redefine a new understanding of cultural heritage. Social media also collects various research strands, especially those related
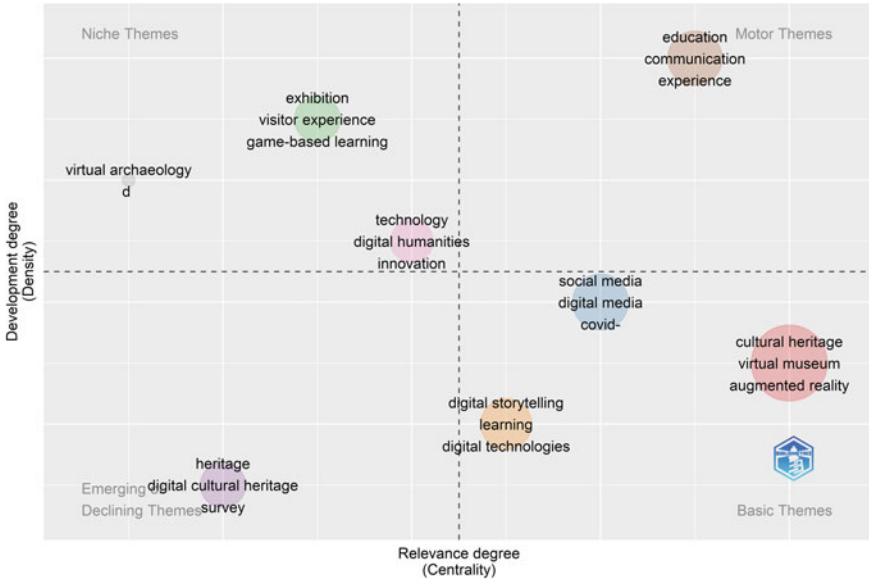
Fig. 12 Thematic map of author's keywords. Elaborated by Bibliometrix

to younger generations. In turn, learning and education are now underpinned by social media and augmented reality. Digital storytelling started as a personalized visit experience to become now a separate research issue.

The intellectual structure is based on a co-citation network of articles that are both cited in another article. In other words, it is "the degree of relationship or association between papers as perceived by the population of citing authors" [75]. The co-citation network visualizes 50 papers on museum digitalization clustered
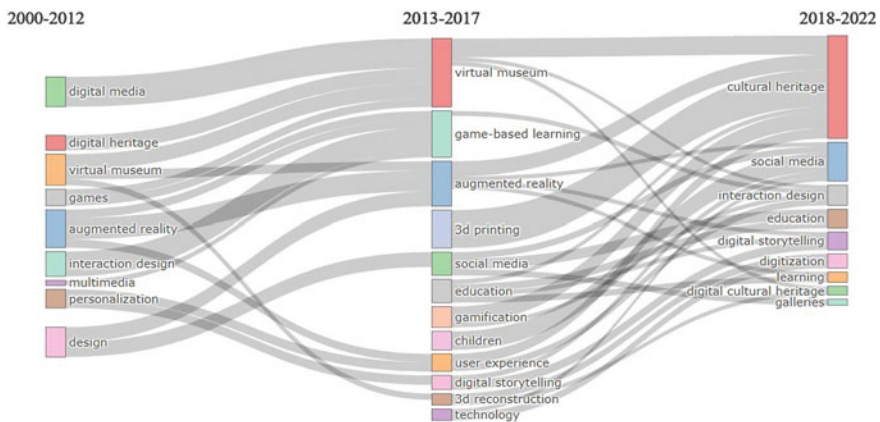

Fig. 13 Thematic evolution map of author's keywords. Elaborated by Bibliometrix

with the Louvain algorithm (Fig. 14). The analysis confirms the existence of 4 main streams of literature: the dimension represents the normalized number of citations received by the paper, and the thickness is the strength of co-citation bonds. Their position indicates centrality in the research field, and their proximity shows the density of the stream of literature.

The red cluster contains the core publications of the bibliographic collection and overlaps with the documents with the most locally cited references we have previously discussed. It is not surprising that red nodes are grouped in the center of gravity of the network. These citations can be summarized with "learning in/at the museum" and are used to build the theoretical framework that aims at educational goals through technologies, experiments, and social engagement. Some are co-cited only internally in the cluster, such as Hein [53], Tallon [5], Capriotti [61], and Parry [57], while others have strong connections with different clusters, such as Simon [25] and Falk [16]. The red sub-set of articles is generally transversal and very well connected with
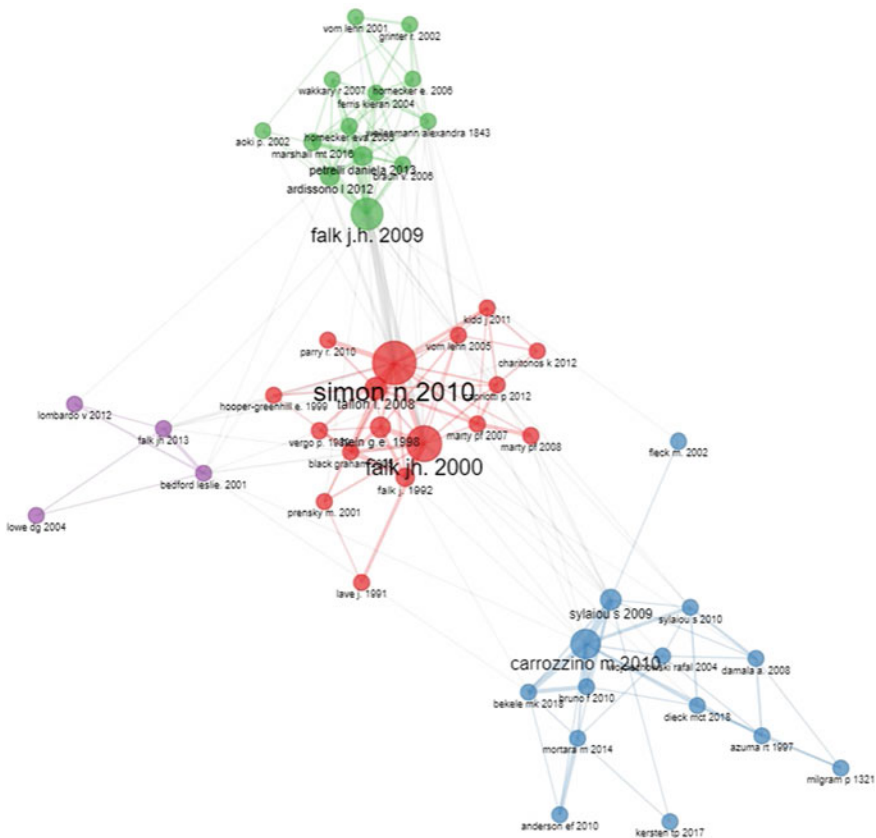

Fig. 14 Co-citation network of articles. Elaborated by Bibliometrix

the green cluster. The latter discusses how to integrate virtual and physical experiences. Falk [51], Petrelli [64], Ardissono [59], and Ferris [76] are the main nodes of this stream of literature that can be labeled as "personalization". The blue cluster is densely populated and more peripheral to the center. We label this stream of literature that covers all issues of immersive reality applied to cultural heritage as "virtual museum", also referring to one of the most used keywords analyzed in this study. Carrozzino [54], Bekele [15], Sylaiou [55], Damala [74], and Mortara [77], represent the main co-cited articles of the cluster.

The small purple cluster that is close to the center of gravity contains the stream of literature that falls under "storytelling", based on Bedford [78], Falk [66], and Lombardo [60]. It confirms the existence of a residual and possibly growing interest in this direction, as shown in our previous analyses.

Finally, we analyze the social structure of the research field by looking at the collaboration network among authors, institutions, and countries.

Co-authorship network identifies research groups working in the same sub-field in order to cluster groups of regular authors and the most influential figures within the analyzed research field [79]. Museum digitalization shows a fragmented collaborative network (Fig. 15).

Most are biunivocal collaborations, such as the three publications in which Benford and Bedwell have worked on ways to augment museum visits with visual markers, hidden objects, or card games. Among three-author research groups, Nisi-Cesario-Coelho shows a robust collaboration around the relationship between museums and teenagers through games and interactive stories. Vayanou-Katifori-Ioannidis have collaborated in 5 publications on personalized storytelling and human-led hybrid guides. A four-author group is composed of Petrelli-Ciolfi-Marshall-Not with significant contributions by the first author and separated collaboration with other authors. These collaborations are generally positioned on the relationship between museum and information, spanning from the Internet of Things to advanced storytelling techniques. Web of Science categorizes their contribution under "computer science". Another solid research group is formed at Università Politecnica delle Marche with Pierdicca-Malinverni-Frontoni-Angeloni-Clini. Their work on digital platforms is especially aimed at archaeological sites. Antoniou-Lepouras-Wallace-Vassilakis-Poulopoulos form the most consistent research group, and the first author also has strong connections with Vayanou-Katifori-Ioannidis, resulting the focus in the wider collaborative network in museum digitalization. Antoniou et al. work on games, guides, and social media engagement for museum visits.

Figure 16 shows the collaboration network of institutions. One populated cluster is formed by Northern American universities and American national academies, having the University of Pennsylvania as the most contributing affiliation with publications concentrated in the period 2015–18. Another populated cluster is led by Greek universities such as the University of Peloponnese and the University of the Aegean, but extended to Universidade de Vigo, Università di Napoli Federico II, University of Glasgow, and the University of York. Among small clusters, Università Politecnica delle Marche has strong collaborations with the Italian National Research Council.
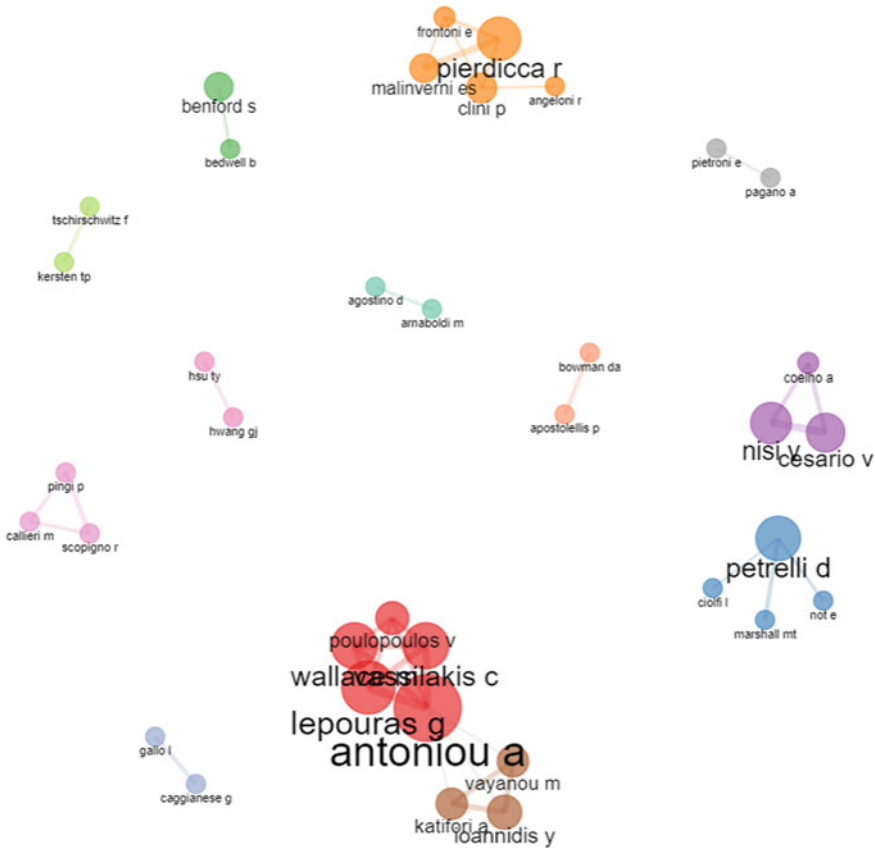
Fig. 15 Co-author network. Elaborated by Bibliometrix

Country-wise, the collaboration network confirms that the main clusters are led by the UK, Italy, and the USA (Fig. 17). The latter is mainly related to Canada and eastern countries; the UK collaborates with all European countries and has the largest reaching network, Italy has a smaller cluster but many collaborations with European countries and American countries. Interestingly, while the UK has very strong collaborations with both USA and Italy, ties are relatively weak between USA and Italy. The clusters mentioned above are very much polarized towards one country; however, a fourth collaborative cluster (purple) is formed by Greece, France, Germany, Spain, and Austria with multiple connections among nodes (distributed network) and central to the analyzed topic of the bibliographic collection. This purple cluster is at the intersection of the other three main clusters. Biunivocal relations are observed between Brazil and Portugal, and Germany and Turkey. It should be mentioned that China is usually among the top contributors in bibliographic analyses [80–82], but in museum digitalization is still not a major contributor and is relatively isolated. Russia, central Asia, and Africa have residual or null impact on the collaboration network.
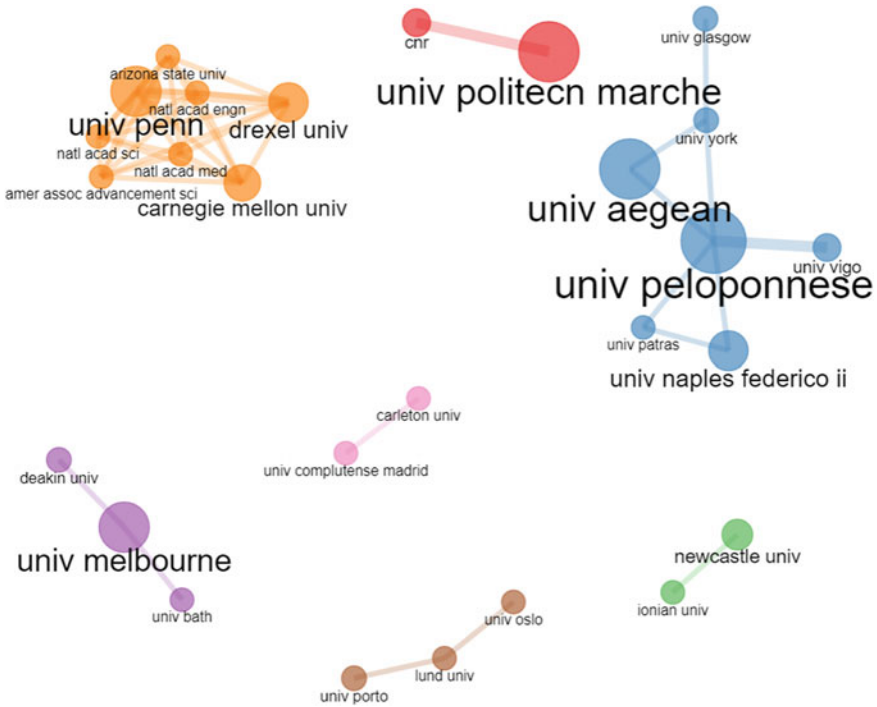
Fig. 16 Collaboration network of institutions. Elaborated by Bibliometrix

3.1 Limitations

This literature review has some limitations. First, the WoS database is one of the main databases and is generally regarded as the source with the highest quality of entries [82]. However, other databases, such as Scopus, might have partially different entries according to the typology of the document [83]. Hence, articles not indexed in WoS have not been analyzed. Second, publications whose abstract language differs from English have not been included as well. Some essential publications in French, Spanish, and Chinese have been excluded. Third, some analyses imply the use of mathematical models that simplify a large amount of data to allow interpretations and visualizations. This process may omit perspectives that are relevant to the study.
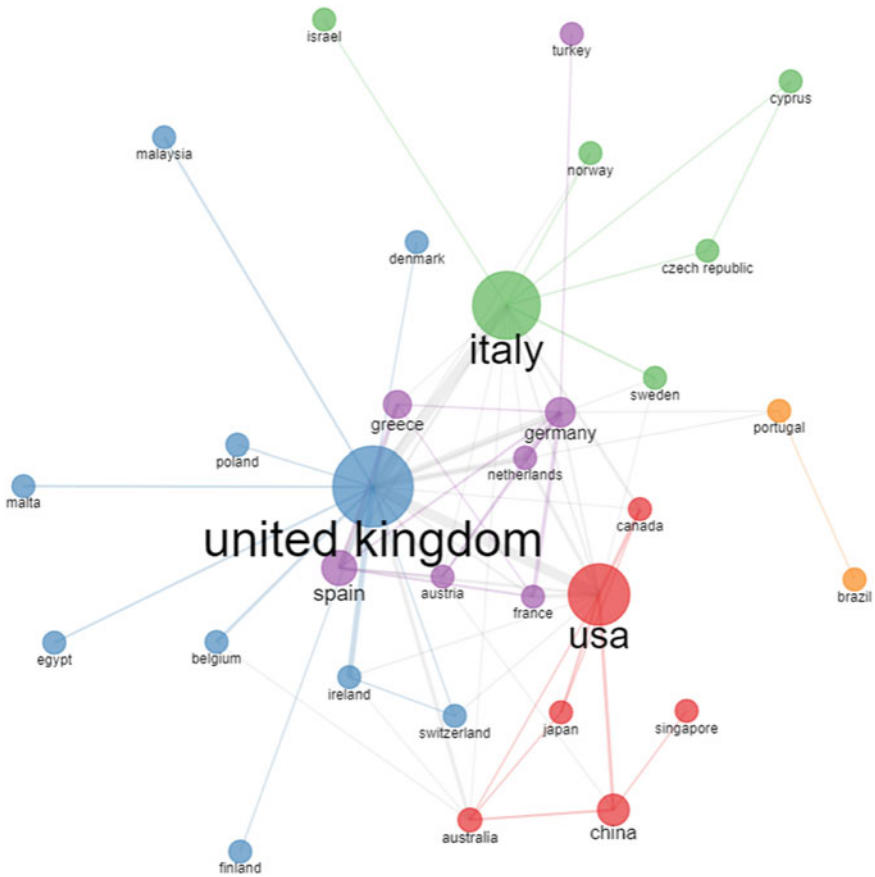
Fig. 17 Collaboration network of countries. Elaborated by Bibliometrix

4 Survey

4.1 Methodology

The survey aims at completing the descriptive quantitative analysis performed in the literature review with a qualitative evaluation of the issue of museum digitalization through interviews with museum professionals. This critical review with a group of experts will highlight similarities and differences with the research strands that we have identified in the literature review. Additionally, we decided to source participants among curators and directors of museums to measure the distance between academic publishing and practice. This will allow us to see if emerging topics in literature align with professionals' opinions.

To achieve maximum exploration of the topic, the questionnaire is composed of open-ended questions so that interviewees can introduce new concepts on museum digitalization. The survey follows a qualitative design through in-depth, semi-structured interviews with ten professionals (Table 2). This group includes seven directors, one curator, one expert in historical heritage conservation, and one expert in digital storytelling. All experts are well-known and affiliated with one of the institutions listed in Table 2. Answers have not been associated with the corresponding institution to guarantee their anonymity.

Table 2 Interviewee affiliation

Museum	Location	Nr of inhabitants	typology	Nr of visitors (2018)*	Nr of visitors (2019)*
Museo Sigismondo Castromediano	Lecce	795.134	Provincial	8000	4000
Museo dell'Ara Pacis	Roma	2.848.084	Civic	216,806	203,586
Museo Archeologico Nazionale di Taranto—MArTA	Taranto	576.756	National-autonomous	73,237	71,032
Museo Archeologico Regionale Paolo Orsi	Siracusa	399.224	Regional	63,239	42,290
Museo internazionale delle marionette Antonio Pasqualino	Palermo	1.253.000	Private	40,000	29,374
Museo archeologico nazionale di Napoli—MANN	Napoli	3.085.000	National	616,878	670,594
Museo Egizio	Torino	2.260.000	National	848,923	853,320
Civico Museo Archeologico	Milano	3.250.000	Civic	70,200	44,930
Museo di Storia Naturale di Venezia Giancarlo Ligabue	Venezia	853.338	Civic	79,870	70,660
Museo Archeologico e d'Arte della Maremma	Grosseto	221.629	Civic	15,033	16,030

Sources *(microdati Istat, Visitatori nei musei del Sistema Musei Civici, Annuario Statistico Roma Capitale, MIBACT, www.museodellemarionette.it, Annuario del Turismo—Città di Venezia, Rapporto Musei 2019 e 2020 Regione Toscana)

To get more homogeneous answers, we have sourced only institutions from one country. Hence, these museums operate under the same regulatory framework. Italy has been chosen for the following reasons:

- As demonstrated in the literature review, Italy is the second most frequent country of origin of authors
- As demonstrated in the literature review, Italy is the second most frequent country of authors' affiliation
- As demonstrated in the literature review, Italy is one of the core clusters of scientific production
- As demonstrated in the literature review, Italian museums have been widely studied with reference to COVID-19 impact [7, 44, 84, 85].

Museums are spread over nine different regions, from north to south. Their typology and size have been differentiated into four civic museums, three national museums, two regional museums, and one private museum. All are positioned in cities of different sizes and administrative statuses: Lecce, Roma, Taranto, Siracusa, Palermo, Napoli, Torino, Milano, Venezia, and Grosseto. Certain centers are more subject to tourism; others have local relevance.

Interviews took place through individual online meetings in April–May 2022, recorded and transcribed by the authors. All participants have been contacted by email or phone and asked to participate in the study. They have been provided with a privacy statement signed by the authors and had the chance to request and review the recorded meetings. The duration of the interview was 45 min up to 60 min.

With the transcripts, we first analyzed the text using the software Voyant to find recurrent words and concepts. Then we performed a qualitative assessment of the answers. Finally, we compared these answers and key concepts with those that emerged in the literature review.

The survey of museum professionals is structured on four key areas that have been highlighted in literature: (1) Digitalization in museums; (2) Engagement; (3) Interaction; (4) Virtual Environments. Each key area is explored with four open-ended questions.

Digitalization in museums. This set of questions generally enquires about the expert's view on the topic. Question 1a asks about the main challenges for a museum in relation to digitalization. Question 2a asks how experts feel about the migration of museums to online platforms (i.e., websites, virtual tours, web galleries, Instagram, etc.) as new forms of engagement. Question 1c asks about the existence and consistency, in their museum, of a department dedicated to the development of digital content and platforms. Question 1d asks about initiatives adopted during COVID-19 restrictions and whether such strategies were further developed after the re-opening to visitors.

Engagement. This set of questions enquires about engagement through digital platforms. Question 2a asks how important is the image and presence of their institution on social media. Question 2b asks whether the target audience of digital programs is the same audience as their in-person programs. Question 2c asks if they have evidence that social media presence increases the museum's engagement with the

public. Question 2d asks what target audience they would like to attract more in the future.

Interaction. This set of questions enquires about interactive experiences during the museum visit. Question 3a asks to list the interactive platforms/systems adopted. Question 3b asks what part of these systems is digital and when they were designed. Question 3c asks to elaborate on the weaknesses of interactive platforms/systems. Question 3d asks if interaction is an essential component of the visitor's experience.

Virtual Environments. This set of questions enquires particularly about inter-active interfaces and their development besides the physical visit to the museum. Question 4a asks if they think that regular employment of virtual tours can engage new visitors in the long term. Question 4b asks what experts think about the contribution of virtual tours to the visitor experience in museums and if the virtual tour can replace the physical visit. Question 4c asks if they provide a virtual tour of the museum. Question 4d asks about their strategy to implement digital content from a distance other than the virtual tour.

5 Results and Discussion

The cities where the ten museums are located range from 220.000 to 3.200.000 inhabitants, while the number of visitors measured as an average of the two-year period before COVID-19 restrictions (2018–19) is between 6000 and 850,000 (Table 2). Most used words during the interview were "audience" and "social", 36 times. The term "virtual" has been mentioned 32 times, and "communication" 27 times. It should be noted that the word "game", although never introduced by the interviewer in any question, has been used 14 times (Table 3). This confirms the rising attention on gamification of the visitor's experience that is evidenced in literature.

Moving to the first key area of the questionnaire, digitalization, for question 1a on main challenges, interviewees affirm the following in order of relevance and process:

Table 3 List of 10 most cited keywords

Word	Frequency (number of times)
Audience	36
Social	36
Virtual	32
Communication	27
Contents	25
Tour	21
Experience	17
Heritage	16
Video	15
Game	14

(1) re-organization of the collection in new catalogues and displays to create a more rational digitalization workflow (30%). (2) make the digitalization functional to: (a) research, (b) communication to the public, and (c) conservation of perishable material (40%). (3) make digitalization more inclusive and accessible to the different target and social strata (40%). While smaller museums express the primary need to digitalize their collection, large museums have already achieved this step and are already focused on the next stage, that of content accessibility. One expert said:

"The challenge is to reach a point of balance between the materiality of the objects and immateriality of digital data". Another expert focused on the inclusivity issue:

To guarantee the utmost inclusion, access should be oriented to all targets and designed through research and digitalization programs. At the same time, differentiated communication channels will adequately reach various types of visitors.

Answers to question 1b on online platforms favor migration to such realms in as much as the message and content of a cultural institution can be communicated to multiple audiences. A specific point of view comes from one expert who considers the transition unnecessary if it is just for the sake of doing it. The online transition becomes substantial when technological innovation goes together with social innovation. One respondent said:

We are working on some hypotheses to be present in the metaverse. I consider the metaverse a chance to fulfill the dream of perfect worlds. These solutions should be supplementary and not alternatives for those with limited time or who visit the museum in groups with a predetermined schedule.

Question 1c on the presence of dedicated digital departments collected 7 "no". Two of the remaining respondents are part of a network of museums in which the communication/digital department is centralized within a broader institutional framework. One expert said:

"The team is transversal. Archeologists work with external experts (videogame, digital, anthropologists, and sociologists). The digital product creates bonds with certain audiences (kids, elderly people, but also visitors from Eastern countries)". They all agree that the job of a digital expert must be continuously coordinated with specialized consultants such as archeologists, historians, art historians, and other professionals. Technicians are not expected to give their contribution independently. Additionally, these services are often performed by external companies because of the lack of specialized staff, making the integration with museum strategies very problematic.

Regarding question 1d on the long-term effect of Covid-restriction, in most cases the work during the pandemic was an implementation phase of strategies that were already active. Initiatives: intensive use of the website and social media; development of digital content and ad hoc virtual programs, detailed studies of specific artworks, 3D videos, conferences, contests, games, online laboratories, live performance in streaming, and digital classrooms. Most of the activities are still operational on digital platforms. Instead, COVID-19 helped to strengthen their presence on social media. Most of the traditional cultural activities (conferences, seminars, performances, and

guided tours) resumed their in-person format. All other activities are still offered online. Only one expert said that they are aiming to return to pre-Covid strategies. Another expert said:

> This forced closure allowed us to become very resilient to changes and to strategize a new way of communicating with the visitors. This communication goes on and must evolve; we should never look back.

In the key area of engagement, question 2a asks about museums' curation of social media image (Table 5). It is seen as a fundamental component. All experts agree on its relevance, although specifying the following caveats: have a strong visual identity, coordinate communication across all different activities, and customize their social media presence on different social media. Facebook is considered by one expert a mere repository of information. For another expert, it's essential to be friendly in order to attract people and create a community. One expert said:

> We use a program called 'travel appeal', created for hotels, that allows us to under-stand visitor's appreciation. It monitors the digital reputation of the museum. This gener-ates a ranking of satisfaction. It is monitored carefully but retains some problems since performances are measured with keywords related to the hotel sector.

Question 2b on the possible overlapping of targets of digital platforms and physical visit received various responses. Two experts agreed on this correspondence. Five experts did not agree, especially considering age differences and respective education to the use of interactive devices. Serious games are mainly used by adults (40–50 years old). In terms of nationality, non-Italian visitors interact more on digital platforms. Two experts affirm that it's not possible to make a difference between the physical and digital public: they are all part of the same community of the museum, and considered at the same level. One expert didn't elaborate specifically on the issue. Noticeable feedbacks are:

> No. [touristic city] is a reality unto itself in the sense that the museum attracts a variable percentage of tourists that pass by and visit the exhibition. Therefore, it is very popular among children and grandparents or families.
>
> No. There is a group of users who follow the web and social pages with interest but do not necessarily become physical visitors. It might happen. The community is transformed into a physical community if there is social awareness. The museum must regain possession of its social centrality; it must be an expression of a community to have a consistent audience.
>
> We must not consider the digital visit inferior and secondary to the physical visit. We must consider all as a single community.

To question 2c on proof of public engagement with digital platforms, two experts answered that it is not possible to give an evaluation on this question because of the COVID-19 restrictions. Eight experts confirm that they have proof that digital platforms increase public engagement. They need to be complementary to the rest of the visit and functional in order to be coherent with the identity of the museum. Two of them said that the number of visits or likes reveals the engagement, but it is not proof of the real impact of the content that has been delivered. One expert pointed out:

Communication with visitors is much easier on social media, but the goal is also to create a physical agora (in gardens, bar, restaurant) to build new spaces for social engagement.

Question 2d on the typology of target that they believe their museum should aim at in the future, over 60 and young people (15–30) are indicated as the preferred targets to be engaged in the next strategies. Two experts mentioned the local community because with them they have the potential to build a long-term relationship. Two experts refer to accessibility as one of the main factors to consider: people with different kinds of disabilities, people who cannot afford technological devices (social disparity), and non-native digital people (older adults). One said:

We will continue to involve the community as much as possible. The 'threshold' effect still blocks the visitor at the entrance. Young people are very hard to attract outside school environments (school visits). We are trying with a dedicated language in communication and with games.

In the key area of interaction, Tabb. 4–5 show a classification of the systems used in museums. Question 3a, asking about interactive activities to be experienced during the visit, received the following list of items, ordered from the most mentioned to the least mentioned:

1. Museum guide
2. App
3. Audioguide
4. Video
5. Touch screen or tablet with database
6. Interactive games
7. Immersive experience for people with visual or hearing impairment
8. Interactive tour with museum guides or performer

One expert said:

The museum is equipped with a visit system focused on artificial intelligence. We have digitized the visit path, and we have a google-centered ecosystem that can be programmed according to the tastes and position of the visitor. According to the target, the age, and the subject of interest, the AI adapts to whoever uses it. This system, however, needs many inputs; the pandemic did not allow its use and therefore the prototype in this period is being tested further.

Question 3b asked whether such interactive experiences are digital and when they were designed. Almost all are based on digital platforms. The guide is considered the first interactive method to create empathy and interest in the visitor. Dramas performed in the visited venue are regarded as an innovative device for one expert. Collateral activities such as performances and interactive visits through a virtual tour can be added to analog interactive methods. The oldest digital platforms date back to 2006, primarily to create digital twins of the collection. Others were designed in 2010 or 2015–2016. Most of them used funds from the European Commission, and the digitalization process in general is still ongoing. One expert mentioned that digitalization started in 2016 with European ERDF funds, "When the museum became

autonomous in 2015, it was possible to create a strategic plan by choosing long-term orientations and guidelines. These kinds of projects need long-term planning".

Question 3c on weak spots of digital platforms was answered primarily with economic sustainability in the long term: maintenance and hiring of external technical experts because of the lack of existing personnel that can guarantee updates and curation of devices/technologies. This is connected to one of the most common weak points, the obsolescence due to continuous updates or shifts in operating systems (i.e., Android, Apple, Windows). Another negative factor is the lack of real interactivity, which can cause lower interest in the physical path in the museum, especially if digital systems are used during the visit. The accessibility of interactive scientific content needs to be improved and made available to people of different backgrounds and education. Concerning virtual tours, the quality of the digital product needs to be very high. Still, they usually present problems that are impossible to overcome, such as light refraction on displays. The alternation of exhibition layouts or display arrangements during the months or the years can be another weak point, especially for museums that cannot afford a different virtual tour every time the visit layout changes. One expert said:

> The visitor should be prepared before the visit. Usually, we assume minimum competence in this regard. In recent times, the level of reading concentration has decreased while the percentage of those who lack schooling is still high. So, we adapt to a zero degree of content to be experienced on digital devices. While the reconstruction of a statue in a temple is an arduous task, the technology that makes this content available to the public should be elementary.

All experts agreed on question 3d that interaction is essential for a visitor. Two experts specified that it is only a component of the visit, especially with digital interfaces. It needs to be customized to the individual experience (personalization) and can be extended before and after the visit.

In the key area of the virtual tour, question 4a asks whether this technology can create long-term engagement. One expert disagreed, six agreed with this statement, two agreed with reservations, and one couldn't say. Most experts confirmed that the regular use of virtual tours could attract more visitors in the long term if it enriches the visit in a process that extends "before, during, and after" the visit. Two of them considered essential the virtual tour only in a few cases in as much as the elements or the space represented no longer exists (virtual reconstruction of an archeological area, for example) or the virtual tour of the museum offers only a partial preview of the visiting experience in presence. One expert said:

> There are initial peaks of great interest, but then the use of the virtual tour reaches a stable level of a small number of users. There is no doubt, however, that in the case of archaeological sites, where what is no longer visible or difficult to reconstruct can be represented by the virtual tour, the virtual visit can be a standalone experience separated from the on-site visit.

On question 4b, on the degree of replaceability of the physical visit with the virtual tour, they all agreed that the virtual tour cannot replace the physical visit except for some cases related to the impossibility of reaching the museum (distance, political issues, disability, etc.) or for objects/areas that no longer exist. Two of them

added that the virtual tour can support the visit as a preview and invitation to join the physical visit. It is crucial to find a balance between the physical and the virtual visit. One expert said:

> If the virtual tour is designed to provide a wide range of additional processed content, which can be transformed into an experience that integrates the material and immaterial, then it makes sense to undertake this path from the point of view of a museum.

Question 4c received eight affirmative responses on the presence of a virtual tour of their museum. Final question 4d, on the perspective of adopting digital experiences different from the virtual tour, received the following answers:

- No (10%)
- gaming (20%)
- digital platform dedicated to cultural heritage (20%)
- film, short film (20%)
- virtual reconstruction of the context in which the collection was based (not existing geographical contest of the past) or the museum is based (exterior and interior) (20%)
- augmented reality
- webGIS: interactive map
- digital storytelling
- 3D reconstruction of the cultural heritage
- podcast
- TikTok.

One expert explained:

> The aspect that is missing in an archaeological museum such as [museum name] is the context: the historical context, therefore the temporal distance that separates us from the time in which the objects in front of us were made, and the environmental context in which they were used. The digital environment can certainly help us to reconstruct both of these contexts.

5.1 Limitations

The interview was conducted with a qualitative methodology on a restricted number of experts. A structured interview with a larger sample of experts, as well as parallel research on other countries, would improve the spectrum of the issue of digitalization from the experts' point of view.

6   Conclusions

The interview offered a starting point to verify keywords, concepts, and directions that emerged within the bibliographic collection. The experts portrayed the state of the art in museum digitalization from the viewpoints of directors and curators that manage cultural institutions on a daily basis. This mixed methodology shows that academic production and practice intersect in most of the topics that emerged through the bibliographic analysis. The stream of literature on "learning in/at the museum" is also present in the interview, but educational goals are not mentioned as primary motivations for the process of museum digitalization. The research topic of "personalization," which investigates the integration of virtual and physical experiences, has a very strong parallel with the topics that emerged from the experts' responses. This is often considered their main concern when adopting digital platforms. Another topic that parallels academic research covers issues of immersive reality applied to cultural heritage, as is tackled in the stream of literature "virtual museum." Both academic researchers and directors have minor but rising interest in digital "storytelling." Experts also confirmed a significant interest in gamification as a way to engage specific targets.

We have verified two primary domains of interest: knowledge and reality. The first involves teachers and students and gives a social aspect to the interaction with the museum. The second examines the different degrees of reality attached to the visitor's experience: the analysis spans from the development and optimization of the devices to the theoretical discussion on the relevance of digital twins for cultural heritage. This implies a question, often present in our analysis, around the existence of a virtual museum.

The educational aspect of museum digitalization shows a more independent development than studies interactive interfaces. This is due to the fact that museums can be the right venue to deliver informal education through immersive experiences or hands-on activities. A thematic museum can expose school-age students to important societal issues, both outside and in collaboration with schools [86]. For instance, such a hybrid cognitive model can be shaped as a mobile learning environment, allowing students to access physical and virtual resources [47]. Alternatively, mobile location-based systems used in the museum are being experimented on teenagers to perform serious games and create new learning scenarios [87].

Issues related to COVID-19 are researched and discussed in relation to social media presence and social media engagement as lessons learned from the 2020–21 period.

Finally, the ultimate goal of museum experts seems to be the personalization of the visit. A customized experience renders strong visitation motives and possible long-term affiliation. This effect can be established with digital and analog interactivity, social engagement, and maximum accessibility.

Appendix

See Tables 4 and 5.

Table 4 Interactive systems used during the physical museum visit

Museum	Digital	Analog
Museo Sigismondo Castromediano	Artificial intelligence	Drama in the museum space, contemporary art show, performances
Museo dell'Ara Pacis	Audioguide, videoguide, video, Augmented Reality, app Sistema Musei Roma Capitale	Guided visit
Museo Archeologico Nazionale di Taranto—MArTA	App Past for Future (videogame), Augmented Reality, Artificial Intelligence	Guided visit
Museo Archeologico Regionale Paolo Orsi	Virtual tour	Guided visit
Museo internazionale delle marionette Antonio Pasqualino	Virtual tour	Interactive guided virtual visit
Museo archeologico nazionale di Napoli—MANN	Extramann app	Interactive virtual tour mediated by the guide
Museo Egizio	Audioguide	Guided visit, guided visit with the director
Civico Museo Archeologico	Tablet with data sheets	Guided visit
Museo di Storia Naturale di Venezia Giancarlo Ligabue	Touch screen, audioguide, interactive rooms, immersive game, audioguide	Tactile visit, tactile visit for the visually impaired, guided visit
Museo Archeologico e d'Arte della Maremma	Video, immersive itinerary for hearing impaired people, immersive itinerary for visually impaired, audioguide	Tactile 3D reconstructions, tactile tables, guided visit

Table 5 Digital systems/platforms disconnected from the physical visit

Museum	Online digital system	platform
Museo Sigismondo Castromediano	Social network	YouTube, Facebook, Instagram
Museo dell'Ara Pacis	Google Arts & Culture	artsandculture.google.com
	Virtual tour	website
	Video-story telling for kids	website
	Video-story telling	website
	App MiC Roma Musei	playstore, app store
	Video on temporary shows	website
	Social network	YouTube, Facebook, Instagram, Twitter
Museo Archeologico Nazionale di Taranto MArTA	Virtual tour 3D	website
	Artsupp	Artsupp website
	Google Arts & Culture (ongoing)	artsandculture.google.com
	MArTA Lab—e-learning lab	website
	Gaming: Past for Future app	playstore, app store
	Social network	YouTube, Facebook, Instagram, TikTok, Twitter
Museo Archeologico Regionale Paolo Orsi	Virtual tour	website
	Podcast	.izi travel
	Google Arts & Culture	artsandculture.google.com
	Social	Facebook, Instagram, YouTube
Museo internazionale delle marionette Antonio Pasqualino	Podcast	.izi travel
	Visual and sound archive	website
	The human library	website
	Pupi archive	website
	Video virtual tour Italian/English/sign language	YouTube
	Social network	Facebook, Instagram, Twitter, YouTube
Museo archeologico nazionale di Napoli	Extramann app	playstore, app store
	Video	website
	Ppodcast	Ohmyguide tours
	Gaming: Father and Son1	playstore, app store
	Gaming: Father and Son2	playstore, app store
	Gaming: manncrafts	Minecraft for PC Java or mobile (Android e iOs)
	Google Arts & Culture	artsandculture.google.com

Table 5 (continued)

Museum	Online digital system	platform
	Open-data	website
	Social network	Facebook, Instagram, YouTube, Twitter
Museo Egizio	Virtual tour	website
	Virtual tour for kids	website
	Google Arts & Culture	artsandculture.google.com
	Social network	Facebook, Instagram, YouTube, Twitter, LinkedIn
Civico Museo Archeologico	Virtual tour	website
	Didactic datasheet	website
	Archive of collection	website
	Informative material	website
	Social network	Facebook, Instagram, YouTube
Museo di Storia Naturale di Venezia Giancarlo Ligabue	Google Arts & Culture	artsandculture.google.com
	Database	website
	Thematic datasheet	website
	Virtual tour	artsandculture.google.com
	Social network	Facebook, Instagram, YouTube, Twitter, LinkedIn
Museo Archeologico e d'Arte della Maremma	Didactic laboratories online	website
	Podcast	.izi travel
	Google Arts & Culture	artsandculture.google.com
	Social network	Facebook, Instagram, YouTube, Twitter

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