

The Current Trend of Virtual Display Design in Museums from a User Experience Perspective: A Thematic Review

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Abstract

At present, the use of virtual technology in museum display design is becoming more and more common, and the related research literature is increasing, its existing mode and trend analysis are still lacking, and the literature review applying the theme analysis method has not been found in previous studies. Therefore, it is necessary to review the existing literature based on the research on the impact of museum virtual display design on user experience and depict the existing research patterns and trends. In this paper, the literature thematic analysis method was used to identify a list of relevant keywords (virtual technology, museum display design, and user experience), and a keyword search was conducted in the WOS database to quantitatively and qualitatively analyze 47 papers. Four final themes were identified in the qualitative analysis section: user experience, virtual technology, interaction design, and content quality. The findings provide new perspectives and frameworks for research trends on factors affecting user experience in virtual display design for museums and provide a theoretical basis for future design practices and researchers focusing on this theme.

Keywords: User Experience, Interaction Design, Virtual Technology, Theme Review

Introduction

Since the 1990s, with the rapid improvement of science and technology, network technology, multimedia technology, virtual reality technology, and other kinds of modern new technologies have been developed rapidly and widely used in various fields of society. Because virtual technology has a high degree of interactivity, realism, illusion, immersion, and other characteristics, so its use in various fields has brought people an unprecedented new experience, so that people have an immersive feeling, which is one of the important reasons why virtual technology is widely used. The impact of museum virtual display design on user experience has become a hot research topic. By analyzing the relevant literature, the

potential and challenges of virtual display design in enhancing user experience can be understood, guiding future research and practice.

Museums play an irreplaceable role as custodians of cultural heritage and as important centers for knowledge dissemination. However, traditional museum presentations may not fully meet the evolving needs and expectations of modern visitors. To enhance the user experience, museums are actively exploring new display design approaches, and virtual technology, as an innovative tool, is increasingly valued and utilized by most institutions. Many studies have investigated how virtual technology can be used to create more engaging and interactive museum exhibitions, revealing that user experience is a key indicator of effective virtual exhibition design. User experience not only influences audience satisfaction and engagement but also reflects a museum's success in digital transformation. Therefore, an in-depth study of virtual exhibition design from a user experience perspective can help museums better meet audience needs. Despite the growing body of research on the technical implementation and design principles of virtual museum exhibitions, there are relatively few systematic reviews on the latest research trends regarding the impact of virtual exhibition design on user experience and its future development. By analyzing relevant studies, we can identify factors affecting user experience in virtual exhibitions and highlight areas for improvement, providing both a theoretical foundation and practical guidance for future design and research. This paper will focus on the literature from 2019 to 2024 on discussing the impact of museum virtual display design on user experience and answer the following question.

RQ: What are the research trends in museum virtual display design from a user experience perspective?

Methodology

This study applies the thematic analysis method to analyze the literature review, using the thematic analysis program ATLAS.ti 9 software as a tool, this method was originally implemented by (Zairul, 2020). Clarke & Braun (2013), believe that thematic analysis is the process of identifying modes and structuring themes through a detailed reading of the literature. Therefore, the sequence of qualitative analysis is to identify modes before structuring themes to know the current hotspots and development trends of museum virtual exhibition design research. The goal of this study is to analyze and interpret the results of the study and make suggestions for future research on museum virtual display design.

The literature selected for this research was obtained from the Web of Science (WOS) database. The selection of literature was based on several criteria:

- 1) The keyword field was set to "all fields".
- 2) The keywords were set to "Virtual Reality" and "Museum Exhibition Design" or "Museum Display Design" and "User Experience".
- 3) The document type is Arrow.
- 3) The literature type was Articles and Conference Papers.
- 4) The publication period is 2020-2024.
- 5) Focus on Museum Virtual Display Design and User Experience.

And6) All literature is in English

The first search resulted in 80 articles (see Table 1), and 53 articles were obtained after eliminating duplicates and invalid articles. The literature was uploaded to Mendeley for data collation, which includes updating author names, uploading source files, and ensuring that the data related to the literature is correct, and finally, 47 valid literatures were obtained (see Fig. 1). The 47 valid documents were exported from Mendeley to ATLAS.ti 9 as the original files, and in the document list, metrics were created for each paper, including 1) author; 2) title of the literature; 3) periodical; 4) year of publication; 5) author's country; and 6) subject area. It will be possible to analyze the current research trends in the literature based on when it was published, the country, the topic, and so on.

Table 1
Search strings from Web of Science

| | | |
|----------------|---|-----------|
| Web of Science | Title, abstract, keywords: virtual reality , museum exhibition design , or museum display design, user experience | 80results |
|----------------|---|-----------|

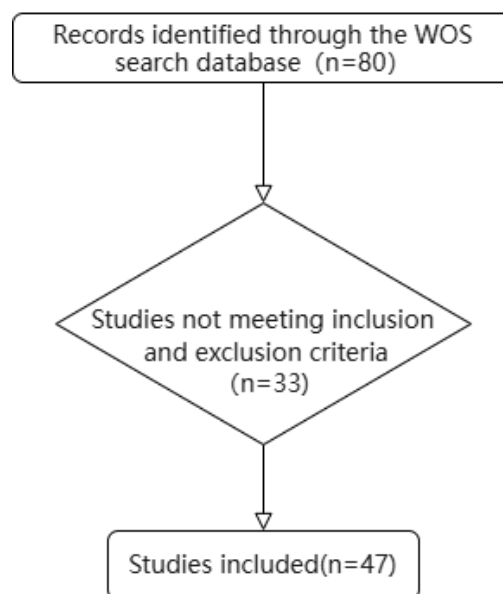


Fig.1. Inclusion and exclusion criteria in the thematic review.

Results

The results are divided into quantitative and qualitative components. The quantitative part resulted in a word cloud generated by analyzing 47 original articles. (see Fig.2). The biggest words in the word cloud are the ones that appear most frequently in the articles, such as “museum” “virtual” “experience”, and so on. As discussed at the beginning of this paper, the main focus of this research is on what are the research trends in virtual museum display design from a user experience perspective.

Quantitative Results

The analysis shows that researchers studying museum virtual display design and user experience chose a variety of different journals, with Applied Sciences-basel and Heritage being the most popular choices in terms of the number of publications for researchers studying museum virtual display design and user experience. (see table 2)

As noted earlier in this article, in this search, if only the keyword 'museum' is used, the results for the number of articles searched would have been in the thousands. However, if the string is limited to "virtual reality" and "exhibition design" or "display design" and "user experience", then the number of search results decreases significantly and the content is more compatible, Therefore, it shows that this topic is still an emerging area where researchers can conduct more research and exploration in the future. Nonetheless, growing research trends indicate that research on these topics is gradually increasing. (see table 3)

Table 2

No. of Articles According to Periodical

| | 2020 | 2021 | 2022 | 2023 | 2024 | Totals |
|---|------|------|------|------|------|--------|
| 2021 Ieee Virtual Reality and 3D User Interfaces (VR) | - | 1 | - | - | - | 1 |
| 2023 Adjunct Proceedings of the 31St ACM Conference on User Modeling, Adaptation and Personalization, Umap 2023 | - | - | - | 1 | - | 1 |
| 29th Cipa Symposium Documenting, Understanding, Preserving Cultural Heritage. Humanities and Digital Technologies for Shaping the Future, Vol. 48-M-2 | - | - | - | 1 | - | 1 |
| 2nd International Conference of the Greece ACM Sigchi Chapter, Chigreece 2023 | - | - | - | 1 | - | 1 |
| ACM Journal on Computing and Cultural Heritage | - | - | - | 2 | - | 2 |
| Advanced Intelligent Systems | - | - | 1 | - | - | 1 |
| Applied Mathematics and Nonlinear Sciences | - | - | - | 1 | - | 1 |
| Applied Sciences-Basel | - | 1 | 1 | 3 | 1 | 6 |
| Computational Intelligence and Neuroscience | - | - | 1 | - | - | 1 |
| Convergence-the International Journal of Research into New Media Technologies | 1 | - | - | - | - | 1 |
| Electronics | - | - | 1 | - | 1 | 2 |
| Electronics (Switzerland) | - | 1 | - | - | - | 1 |
| Frontiers in Psychology | - | 1 | - | - | - | 1 |
| Frontiers in Virtual Reality | - | - | - | 1 | 1 | 2 |
| Heliyon | - | - | - | 1 | - | 1 |
| Heritage | - | - | - | 2 | 1 | 3 |
| Heritage Science | - | - | - | - | 1 | 1 |
| Ieee Access | - | - | - | 2 | - | 2 |
| Information | - | 1 | - | - | - | 1 |

| | | | | | | |
|--|----------|----------|-----------|-----------|----------|-----------|
| International Conference Florence Heri-Tech: the Future of Heritage Science and Technologies | 1 | - | - | - | - | 1 |
| Journal of Ancient History and Archaeology | 1 | - | - | - | - | 1 |
| Journal of Sensors | - | - | 1 | - | - | 1 |
| Journal on Computing and Cultural Heritage | 1 | - | - | - | - | 1 |
| Mathematical Problems In Engineering | - | - | 1 | - | - | 1 |
| Multimedia Tools and Applications | - | - | 1 | - | - | 1 |
| Multimodal Technologies and Interaction | 1 | - | - | - | - | 1 |
| Museum Management and Curatorship | - | - | - | 1 | - | 1 |
| Sage Open | - | - | 1 | - | - | 1 |
| Scientific Reports | - | - | - | - | 1 | 1 |
| Second International Conference on Environmental Geography and Geography Education (Icege) | 1 | - | - | - | - | 1 |
| Sustainability | - | - | - | 1 | - | 1 |
| Systems | - | - | 1 | - | - | 1 |
| Technologies | - | 1 | - | 1 | - | 2 |
| Virtual Reality | - | - | - | - | 1 | 1 |
| Wireless Communications \& Mobile Computing | - | - | 1 | - | - | 1 |
| Totals | 6 | 6 | 10 | 18 | 7 | 47 |

Table 3
Authors According to Themes

| | Interaction Design | Quality of Contents | of User Experience | Virtual Technology |
|---------------------------|--------------------|---------------------|--------------------|--------------------|
| Alabau et al.(2024) | √ | | √ | |
| Bai(2022) | √ | | √ | |
| Ben Guefrech et al.(2021) | | | | √ |
| Besoain et al.(2021) | | | √ | √ |
| Bolognesi et al.(2023) | | | | √ |
| Cantone et al.(2023) | | | √ | |
| Capece & Chivaran(2020) | | √ | √ | |
| Cesario & Nisi(2023) | | √ | | |
| Chen et al.(2021) | | √ | | |
| Chen et al.(2022) | | | √ | |
| Christou et al.(2022) | √ | | | √ |
| Comes et al.(2020) | | √ | | √ |
| Elsharkawy et al.(2021) | √ | | | √ |
| Giovannini & Bono(2023) | √ | | | √ |
| Gong et al.(2024) | | | √ | √ |
| Hu et al.(2023) | √ | | | |
| Hulusic et al.(2023) | | | | |
| Jiang et al.(2022) | | √ | √ | |
| Jin et al.(2022) | √ | | √ | √ |

| | | | | |
|---------------------------|---|---|---|---|
| Kontopanagou et al.(2021) | | | | √ |
| Li et al.(2023) | | | √ | |
| Li et al.(2022) | √ | | | |
| Mahamad et al.(2022) | √ | √ | | √ |
| Manzollino et al.(2023) | | | | √ |
| Meng et al.(2022) | | √ | √ | |
| Micoli et al.(2020) | √ | | | |
| Parker & Saker(2020) | | | √ | |
| Pattakos et al.(2023) | √ | | | |
| Rikhtehgar et al.(2023) | | | √ | |
| Sapto et al.(2020) | | | | √ |
| Shi et al.(2023) | | | √ | |
| Song & Evans(2024) | | √ | √ | |
| Sylaiou et al.(2024) | | | √ | |
| Tennent et al.(2020) | | | √ | √ |
| Tian et al.(2024) | | | | √ |
| Tsita et al.(2023) | | | √ | |
| C.-M. Wang & Tseng(2023) | √ | | | √ |
| Wang et al.(2023) | | | √ | |
| Wang & Meng(2023) | | | √ | |
| Wu et al.(2022) | | √ | | |
| Xu et al.(2024) | | | √ | √ |
| Yi et al.(2024) | | √ | √ | |
| Yoo et al.(2023) | | | √ | |
| Zhang & Liu(2023) | √ | | | √ |
| Zhao et al.(2023) | √ | | | √ |
| Zhuang et al.(2022) | | | | √ |
| Zidianakis et al.(2021) | √ | | | √ |

Secondly, in terms of geographic distribution, related studies have shown a popular trend in China. Gong et al(2024), assured the validity of the VRCHE model by examining the model, new user experience (UX) elements, and new causal relationships between them summarised, aiming to give visitors a certain experiential value in the coherence between reality and virtual reality. Jin et al (2022), discuss how the interaction design of different user interfaces in AR affects the viewer's sense of presence and narrative engagement. Meng et al (2022), investigated the relationship between user experience and website quality in the construction of current digital museums by analyzing the constituent elements of 20 digital museums, distilling three models with differing trends, and evaluating their user experience through experiments. Zhao et al (2023), presented a virtual reality (VR) based 3D modeling technique and human-computer interaction algorithm, and the experimental results showed that most people found the integration of VR technology into the exhibition hall experience to be highly appealing. Researchers from Italy have focused on enhancing the user experience through improvements in virtual technology. It is argued that the visitor experience can be improved by creating personalized virtual scenarios through generatable 3D models (Giovannini & Bono, 2023). Micoli et al (2020), also argued that the effective design of

interactive apps for museum collections can help to complete and integrate the user experience in conjunction with complementary information. Capece & Chivaran's (2020) research emphasizes the spatial and temporal connection between users and technology, as well as storytelling methods and interactive, engaging, and sensory visitor museum experience. The UK, which is on par with Italy in terms of publication volume, focuses more on the impact of the content provided by virtual technologies on the user experience. The findings of Song & Evans (2024), show that Extended Reality (XR) can provide new dimensions of interaction between visitors and exhibits, thus enhancing museum curatorial and exhibition practices, and enhancing the visitor experience by deepening immersion and interaction. Parker & Saker (2020), explore the impact that VR may have on the spatial and social experience of a museum. (see Fig.4)

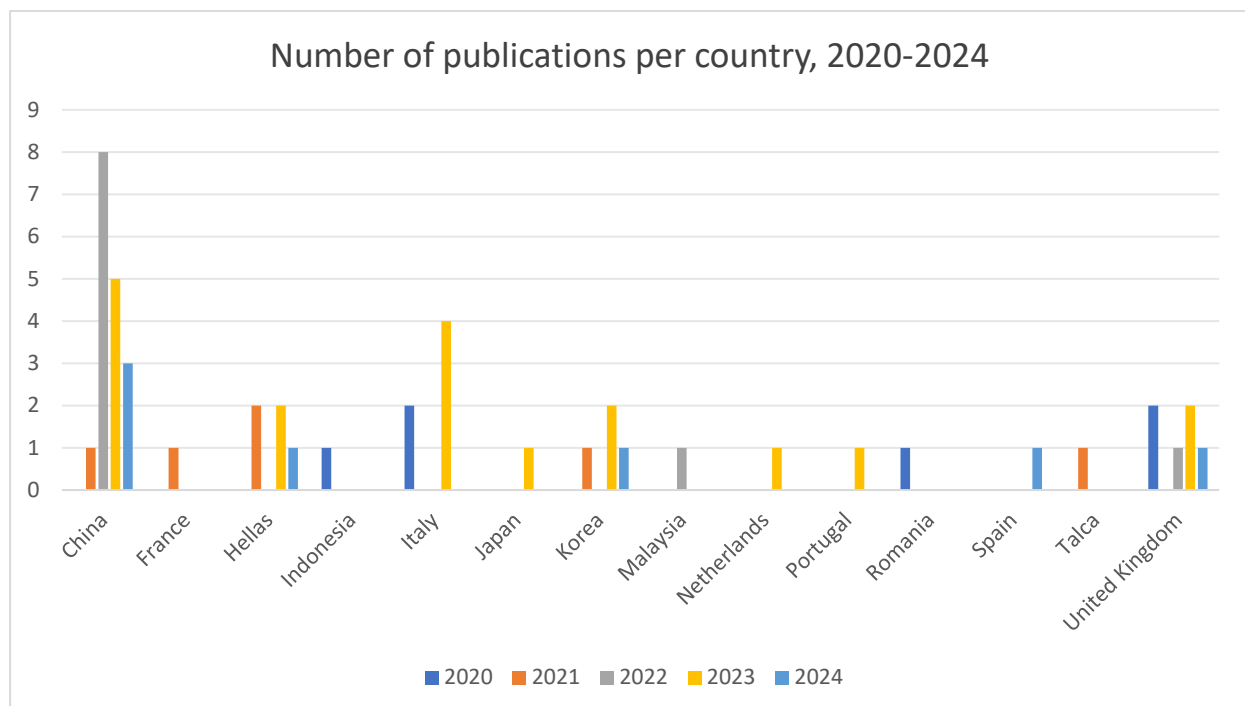


Fig.4. Articles based on country published.

Qualitative Results

In the qualitative part, the paper will establish the relevant themes based on the questions posed, and carefully discuss and answer questions around these themes. Based on the direction and content of the articles, four themes were established: 1) user experience; 2) virtual technology; 3) interaction design; and 4) content quality. These themes do not stand alone; some articles may cover more than one theme, while others may focus on a single theme. In the next section, we will discuss each of these themes and explore the research question - what are the trends in the impact of museum virtual display design on user experience? (See Fig. 5)

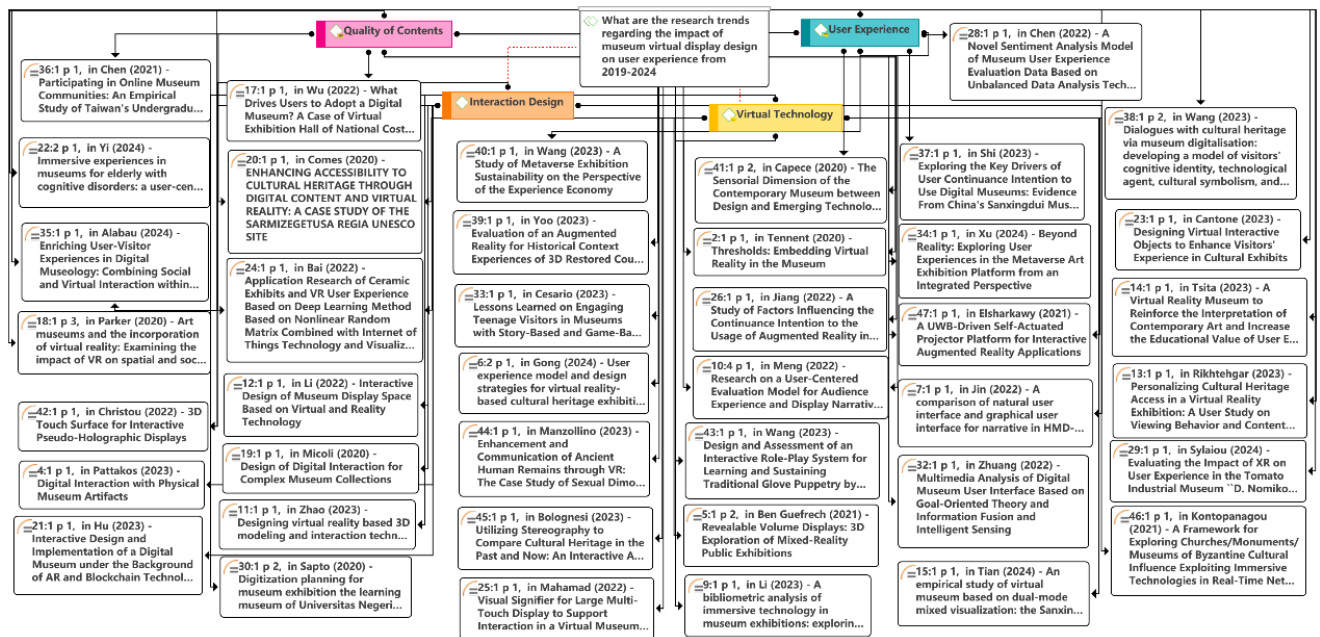


Fig.5.The overall thematic review formulation.

User Experience

In the analysis, it was shown that researchers paid the most attention to user experience, with almost 47% of the articles related to this topic. User experience has now evolved into a comprehensive, multidisciplinary field involving psychology, design, technology, and business. Song & Evans (2024), have developed a design framework specifically for designing multi-channel museum curation and multi-sensory visitor experiences through an ontological understanding of museum curation and user experience, which enhances the visitor experience through deeper levels of immersion and interaction and contributes to the experience economy. This is to fit the user's needs and purpose with the product design as the starting point and ultimate goal of the design. Tsita et al (2023), improved the VR museum application by taking the user's perspective and evaluating the experience of three types of users: museum professionals, technologists, and general audience members to enhance the user experience. Through user research, designers can obtain insights into the needs, expectations, and behavioral patterns of users, which include users' feelings and evaluations of the product's functions, interface, interaction, etc., thus providing a strong basis for product design and improvement. Yi et al (2024), established a user requirement mining method that combines the KANO model with hierarchical analysis. The Kano-AHP method is more accurate than traditional design study methods in catching special user requirements and can identify and refine user needs analysis more effectively. In this design, users are considered decision-makers and evaluators of product design, and their needs and expectations become the driving force of the design. This design philosophy emphasizes the integration of users' needs and purposes with the product's functionality, interface, and interaction design to create a better user experience.

In this theme, we judge that researchers are paying more and more attention to the experience and feelings of user groups, and pay more attention to the user's perspective, through observation, interviews, surveys, and other means to understand the user needs, expectations and behavior of the method to provide a strong basis for product design and improvement. (See Fig. 6)

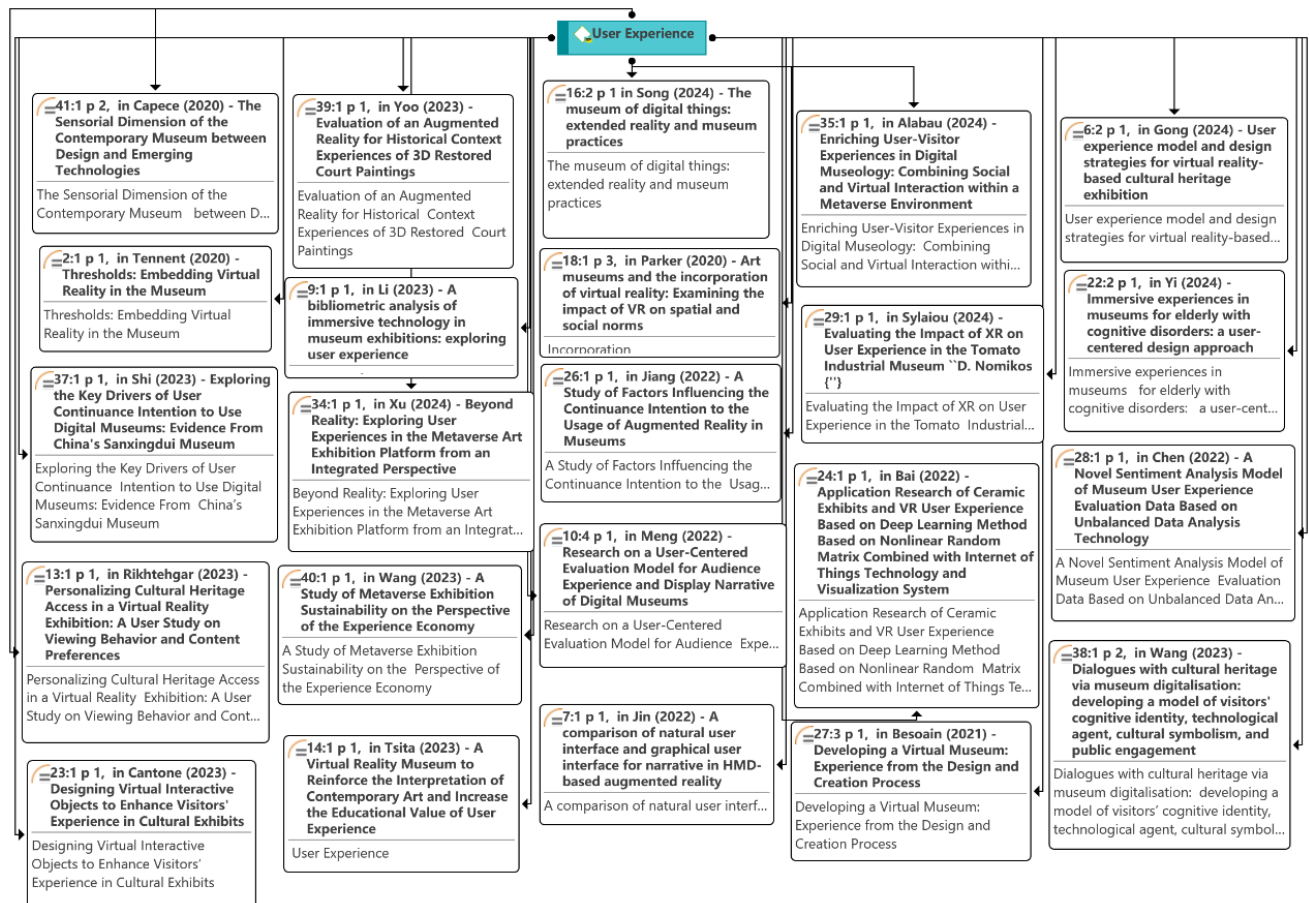


Fig. 6. User experience theme network.

Virtual Technology

With the advancement of virtual technology, the form of museum exhibitions and the way users exhibit are undergoing profound changes, and virtual reality technology can provide audiences with a richer visiting experience, in this context, researchers have begun to focus on the use of virtual technology to improve the way museum’s exhibit. Designers are committed to the development and design of user-friendly interfaces that enhance audience engagement and immersion by introducing interactive elements and personalized recommendations. The concept of Revealable Volume Displays, proposed by Ben Guefrech et al(2021), is a mixed reality display that displays appropriate content entirely by user interaction, which maximizes user interaction with the exhibition, enhances the sharing function, allows all visitors to perceive the exhibit information correctly, and further protects the security of physical artifact. The application of virtual technology in museums can enable visitors to have a deeper impression of the traditional exhibition forms of museums, combining virtual and physical entities and deeply integrating cultural relics with their information so that museums can further play their role in cultural dissemination. Zhao et al(2023) found through a survey of the interviewees, that people can instinctively interact with and identify the environment during the process of actively exploring and experiencing VR, the computer can track the user's movements and give feedback in real-time, and the different interaction methods improve the interest of the exhibition and the audience's sense of engagement. The digital museum created by Tian et al(2024) not only blurs the boundaries between reality and the virtual, fact and imagination but also analyses the visual cognitive, and aesthetic responses of participants in different environments, a model that can provide

spatial and temporal experiences that are in line with those of the real world, as well as bringing about hyper-realistic visual effects. The combination of virtual technology and display in museums has not only changed the traditional way of exhibition, making the form and content of museum exhibitions more effective and richer, but also broken the traditional mode of exhibition as the main body, and started a user experience-led design mode to create a richer visiting experience. Whilst there is great potential in the use of virtual technologies in museum display design, several challenges and limitations remain. For example, factors such as the cost of technology, equipment requirements, the need for high-performance computers and special equipment to support virtual technology, and user acceptance may affect the practical application of virtual display design; therefore, future research needs to further explore how to overcome these problems to achieve sustainable development of virtual display design in museums. (See Fig. 7)

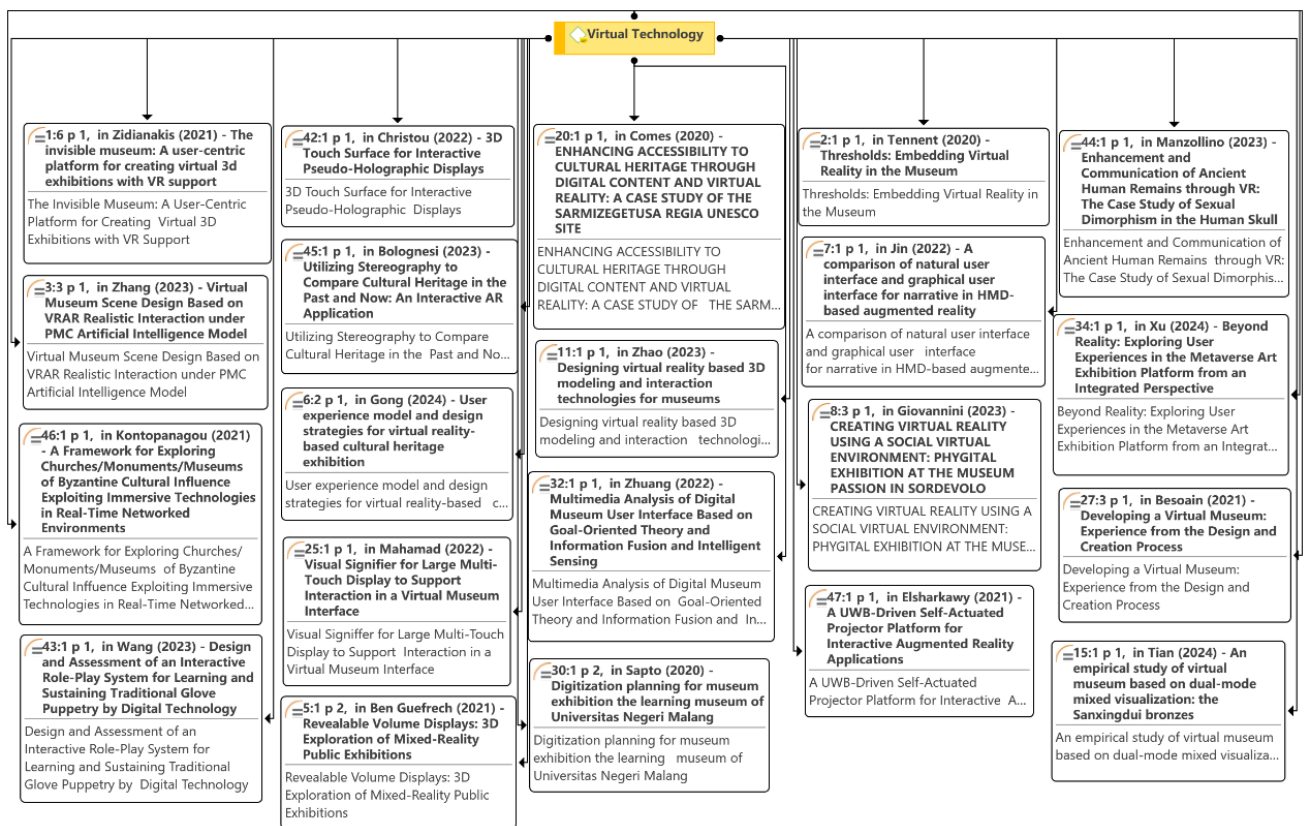


Fig. 7. Virtual technology theme network.

Interaction Design

Interaction design is an important branch in the field of design, focusing on the interaction between users and products. Virtual displays in museums also need more interaction between users and exhibits to achieve the purpose of relaying information about the exhibits and creating an intuitive and pleasant user experience. Different interaction designs will have different experiential effects. Wang & Tseng (2023), showed that the design and development principles of interactive system prototypes follow the 3E metrics, a simple but effective interactive system that allows users to choose and satisfy their needs, and allows users to enjoy a sense of enjoyment and fulfillment during the interaction process, Christou et al (2022), designed and developed a trans-3D touch surface that allows for more direct and rich user interactions with 3D virtual objects, where the user interacts with the display

through a variety of touch gestures, which allows the user to feel that they are interacting directly with the 3D virtual objects, thus improving the user experience. Mahamad et al (2022), designed appropriate visual symbols for the large display virtual museum interface, which can enable users to interact better when using the virtual museum community. Bai (2022), integrates interaction design concepts into the immersive experience and viewing effect of the works, which enhances the physical and mental comfort of users when visiting the works. At the same time, through the smooth control of interactive devices, it realizes the whole demand for virtual art museum art presentations. With the advancement of AI technology, future interaction design will pay more attention to how to use these immersive technologies to enhance the interactive experience between users and exhibits, explore how to personalize the design according to user's preferences and behaviors, and how to enable users to perceive and interact with each other on a deeper level, thus enhancing their sense of participation and satisfaction. (See Fig.8)

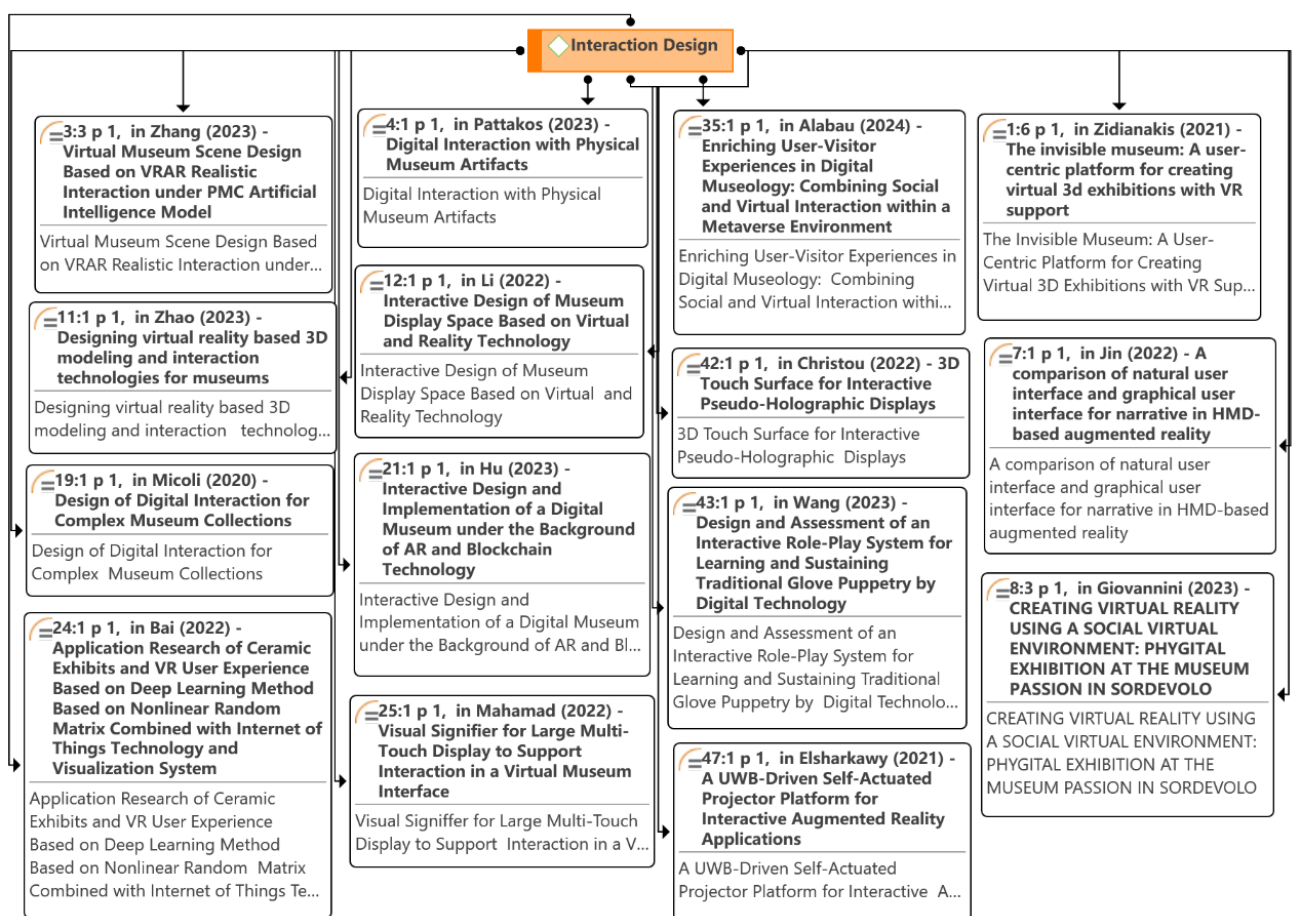


Fig.8. Interaction design thematic network.

Content Quality

The content richness of virtual display design not only affects user engagement and satisfaction but also directly relates to the effective communication of information and the overall user experience. Meng et al (2022), argued that the content presented on a digital museum website has an impact on the user experience, and therefore constructed a prototype of the digital museum experience to explore the impact on the user experience in terms of website quality, user attitudes, and user intentions. Wu et al (2022), demonstrated

that a digital clothing museum can improve information quality and richness and that digital richness and quality have a positive impact on users' perceptions and improve their perceived performance. Jiang et al (2022), showed that not only does information quality have a positive impact on user satisfaction and perceptual interest, but that information quality embodies the value of the user's requirements, and that efficient, accurate, truthful, and usable information quality can be more user-friendly and promote knowledge comprehension, thus increasing satisfaction with the museum experience. High-quality content usually contains rich visual and auditory content and more interactive elements, such as videos, animations, 3D models, etc., which can convey information more clearly, help users better understand the topics and products on display, and better attract users' attention. Although existing studies have shown that website content, information quality, and other factors affect user experience, the exploration of the differences in the experience of different user groups (e.g., age, cultural background, education level, etc.) in digital museums is still insufficient, and there is no clear distinction between the specific mechanisms of various types of information quality (e.g., accuracy, timeliness, completeness, etc.) on the user's perceptions and satisfaction. (See Fig. 9)

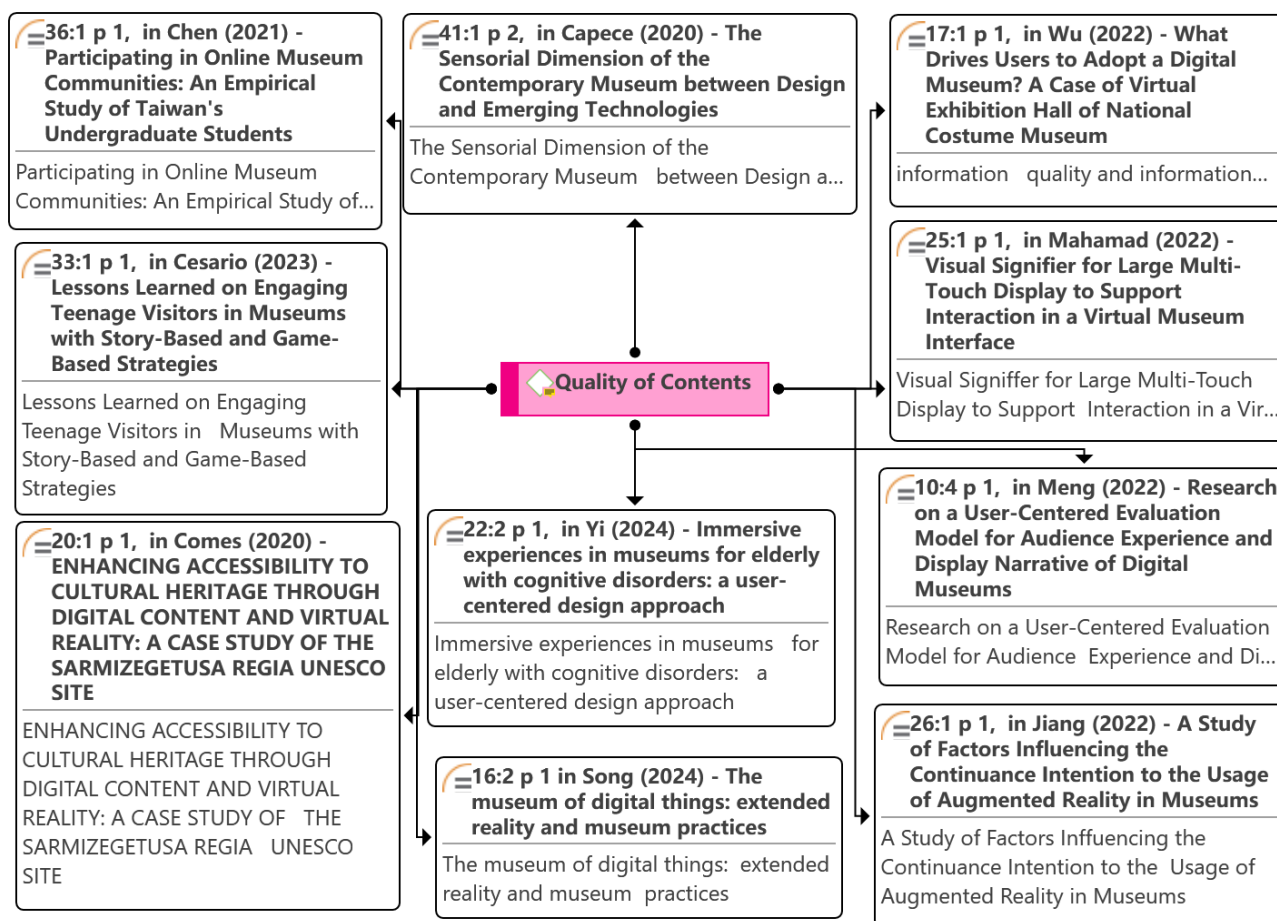


Fig. 9. Content quality thematic network.

Discussion and Future Research Direction

According to this study for the collection of literature, combined with the current research hotspots about the museum virtual display design research affecting user experience, the research direction of this topic is proposed: 1) Based on the collection of user

feedback information, explore user preferences and behavioral data, study how to use data analysis to provide personalized display content and recommendations, assess the effect of virtual display and user satisfaction, and explore the different evaluation methods (e.g., questionnaires, interviews, behavioral analyses, etc.). 2) How the interactive elements when users are in virtual environments or using virtual technologies can enhance the users' sense of participation and immersion. 3) Researching the elements that affect the user's experience of interacting with virtual devices, evaluating the influence of different design symbols on the user's interaction process, and how to utilize intuitive and easy-to-use interaction processes to improve the user experience. 4) Presentation Different ways of presenting content and conveying information in the process have different impacts on users' reception and understanding of information, and how to enhance users' learning effects according to content presentation and information conveyance.

Conclusion

Two approaches have been used in this paper in reviewing the 47 articles. The first one is the quantitative part, which mainly shows the data obtained by analyzing the values in ATLAS.ti 9. Although there is a rising interest in this subject among researchers, there is still a lack of existing literature analyzing research trends on the impact of virtual display design in museums on the user experience. The second is the qualitative component, where the literature was analyzed and discussed using ATLAS.ti 9 for thematic coding. The overall results of the analysis show that the integration of museum display design with virtual technology is becoming more and more prevalent, and researchers are paying more and more attention to the user experience, which can be further enhanced by constantly trying to improve the interaction between users and virtual technology and enrich the information content delivered by virtual products.

The main theoretical contribution of this paper is to analyze the relevant literature on virtual exhibition design in museums. Through a systematic review of user experience and museum virtual exhibition design, this study identifies patterns and trends in the current literature regarding how the integration of museum exhibition design and virtual technology impacts user experience. It provides an integrative perspective to bridge gaps in existing research and serves as foundational information for academic inquiry in related fields. The practical contribution of this paper is to offer insights into improving or enhancing factors that affect user experience in virtual museum exhibition design. It encourages museums to focus more on audience needs in virtual exhibition design, explore effective design strategies and methods, and foster the integration of technology and art. This paper not only presents key findings from current research but also highlights potential directions and priorities for future studies, motivating both academics and practitioners to explore user experience applications in virtual museum exhibition design. In light of the transformation pressures faced by museums worldwide, this study provides practical recommendations for designing and implementing virtual exhibitions in the digital age, helping museums to better define their roles and values in the new cultural communication environment.

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