Bibliometric and Visualization Insights: Understanding the Trend in the Application of Serious Games in Cultural Heritage

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ABSTRACT

Serious games have become one of the most promising ways to display and disseminate cultural heritage. Institutions and scholars have become increasingly interested in developing serious games in cultural heritage in recent years, and relevant academic results have been outstanding. Still, a lack of comprehensive analysis of publications in this field exists. This study aims to analyze the current status and trends of the application of serious games in cultural heritage. This article adopts bibliometric methods through a strict screening process, identifies 156 relevant articles from the Web of Science database, and uses VOSviewer and Scimago Graphica tools to conduct a comprehensive analysis. The results of this study are expected to enrich the knowledge base of the research field, providing insights into the current landscape, research hotspots, and development trends of this interdisciplinary field and offering insights into future research directions.

KEYWORDS: Serious games, Cultural heritage, Bibliometric analysis, VOSviewer

1. INTRODUCTION

Serious games are digital games that are not purely entertainment but contain educational elements (Abt, 1970). With the development of digital game-based learning education theory and digital technology, serious games have been widely used in various fields. Today, serious games are used in different fields, including education, training, cultural heritage, and healthcare (Laamarti et al., 2014). As a kind of digital technology, serious games play a unique role in the digital protection and display of cultural heritage.

Serious games have emerged as one of the most promising ways to support cultural heritage inheritance through experiential learning (Jinyu & Xuefang, 2020). Many relevant studies have shown that serious games can not only provide some cultural education, but also support cultural preservation, replication and appreciation of heritage and promote cultural awareness (Bonacini & Giaccone, 2022). For example, through pre-and post-tests, the i-Treasure project, funded by the European Union’s Seventh Framework Programme (FP7), verified that serious games are effective for beginners to learn intangible heritage knowledge and skills (Dimitropoulos et al., 2018). Evaluation results of a serious game called Papakwaqa show that it can significantly improve students’ motivation and performance in learning about indigenous life and history (Huang & Huang, 2013). At the same time, some studies have shown that serious games have a strong potential for education in museum environments (Doulamis et al., 2012), the restoration of historical sites, and the learning of relevant historical knowledge (Andreoli et al., 2018). The features of serious games, such as human-computer interaction, collaborative learning, reward mechanism, and immersion, make it easier for the young generation to take the initiative to learn and practice and realize self-exploration and creation (Xu et al., 2022).

In recent years, more and more scholars have begun to pay attention to the application of serious games and summarize it. There has been some bibliometric research on serious games, such as an analysis of the use of serious games in healthcare (Wang et al., 2022), an analysis of gamification in math learning (Elmawati et al., 2023), and an analysis of research trends in serious games focusing on researchers, institutions, countries, and subject areas (Irmade et al., 2021). However, bibliometrics studies have yet to take a holistic view of the application of serious games in cultural heritage. This study aims to summarize the present state of serious game applications in the cultural heritage field to suggest future research trends. Over the past few years, bibliometric methods have become popular...
as a systematic evaluation approach for publications (Ellegaard & Wallin, 2015). Bibliometrics, as a scientific specialty, can help scholars understand the research status and identify trends in application fields through quantitative analysis (Schoebel et al., 2021). Therefore, we use bibliometric methods to understand the literature performance of serious games in cultural heritage, determine its scientific progress, reveal research hotspots, identify the most influential journals, institutions, and countries, and predict future trends.

The remaining research framework of this article is as follows. The second part introduces the research methodology and data sources. The third section presents the results of the bibliometric study. Section 4 discusses important research questions. Section 5 draws conclusions and examines limitations.

2. METHODS AND DATA SOURCE

2.1 Methods

This study identified bibliometric and visual analysis methods using the Web of Science (WOS), VOSviewer, and Scimago Graphica tools. WOS is one of the main tools for searching and evaluating publications and journals in different disciplines. Compared with other literature database platforms, it is recognized by many scholars internationally for its high-quality standards (Gaviria-Marin et al., 2019; Vlase & Lähdesmäki, 2023). Therefore, we selected the WOS core collection database as the literature source. With the excellent bibliometric visualization capabilities and well accepted as one of the most widely used software, VOSviewer performs primary cartographic analysis and generates maps based on network data (Bukar et al., 2023; Elmawati et al., 2023). While, Scimago Graphica, as a software for geographic visualization image drawing of countries, it supports high-precision geographic data processing and image generation, which can accurately display geographic information of countries and regions (He et al., 2022; Li, 2023).

2.2 Data Source

This study extracted scientific publications concerning the application of serious games in cultural heritage from the Web of Science Core Collection database as of February 22, 2024. Taking the scopes of searching topics covering "Serious game*" OR "video game" OR "computer game" OR "digital game" OR "educational game", and "cultural heritage", 209 studies were identified from the database. After excluding the duplicates, non-English and review articles, 196 references are included. Finally, by reading the title and abstract of each article, 2 references without full text are excluded and 38 articles with irrelevant titles and abstract contents are excluded too. Therefore, a final total of 156 eligible articles are exported in plain text for bibliometric analysis. Figure 1 shows the selection procedure based on the PRISMA guidelines. Figure 2 shows that the annual number of articles has an overall upward trend in waves as time passes. Only one article was published in 2024 because the literature search was in February 2024, and the number of articles in that year was incomplete. The earliest published relevant study was written by Kalay and Grabowicz (2007) and published in the International Journal of Architectural Computing in 2007. It explores the application and impact of electronic games in the entertainment and communication of cultural heritage (Kalay & Grabowicz, 2007).

Figure 1: PRISMA Flow Diagram of Study Selection
From 2007 to 2013, the development trend remained relatively stable, with an average of only about 2.7 publications per year, indicating that the field is still in the development stage and researchers are beginning to invest in research. From 2014, publications increased significantly, with two peaks in 2019 and 2021. Over the past five years, 81 articles have been published, accounting for more than half of the documents in the final dataset, indicating that an increasing number of experts and scholars are paying attention to the application of serious games in cultural heritage. Figure 2 also shows that the frequency of citations shows a significant growth trend, with 6 citations from 2007 to 2013, 151 citations from 2014 to 2018, and 745 citations in the past five years. Among them, 206 citations are the highest in 2022, indicating the rapid growth of academic influence in this field. It will have a profound impact on related disciplines.

3. RESULTS

This section presents bibliometric results for different performance indicators, including leading research areas, journal sources, institutions, countries, and co-occurrences of author keywords.

3.1 Research Areas

In this study, we first analyzed the main research areas. As seen in Table 1, among the 156 documents, the top five Research fields are Computer Science (~60%), Education Educational Research (~18%), Information Science Library Science (~13%), Arts Humanities Other Topics (~12.2%), Engineering (~11.5%). The study’s primary focus is Computer Science and Education Educational Research. In addition, some studies also involve Archaeology, Imaging Science Photographic Technology, Science Technology Other Topics, Architecture, Social Sciences Other Topics, Art, Remote Sensing and Telecommunications, indicating that research on the application of serious games in cultural heritage is multidisciplinary and interdisciplinary.

Table 1: Top 10 Subject Areas

<table>
<thead>
<tr>
<th>Research Areas</th>
<th>Record Count</th>
<th>% of 156</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Science</td>
<td>93</td>
<td>59.615</td>
</tr>
<tr>
<td>Education Educational Research</td>
<td>28</td>
<td>17.949</td>
</tr>
<tr>
<td>Information Science Library Science</td>
<td>20</td>
<td>12.821</td>
</tr>
<tr>
<td>Science</td>
<td>19</td>
<td>12.179</td>
</tr>
<tr>
<td>Arts Humanities Other Topics</td>
<td>18</td>
<td>11.538</td>
</tr>
<tr>
<td>Archaeology</td>
<td>9</td>
<td>5.769</td>
</tr>
<tr>
<td>Imaging Science Photographic Technology</td>
<td>9</td>
<td>5.769</td>
</tr>
<tr>
<td>Science Technology Other Topics</td>
<td>9</td>
<td>5.769</td>
</tr>
<tr>
<td>Architecture</td>
<td>8</td>
<td>5.128</td>
</tr>
<tr>
<td>Social Sciences Other Topics</td>
<td>7</td>
<td>4.487</td>
</tr>
<tr>
<td>Art</td>
<td>6</td>
<td>3.846</td>
</tr>
<tr>
<td>Remote Sensing</td>
<td>4</td>
<td>2.564</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>4</td>
<td>2.564</td>
</tr>
</tbody>
</table>

3.2 Influential Journals

Table 2 shows that the ACM Journal on Computing and Cultural Heritage (1st, 11 articles) is by far the most active journal, publishing the most articles in the field of research on the application of serious games in cultural heritage. Digital Presentation and Preservation of Cultural and Scientific (2nd, 9 articles) followed closely and achieved significant research results in this field.

Table 2: Top 3 Source of Provenance

<table>
<thead>
<tr>
<th>Source</th>
<th>Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM Journal on Computing and Cultural Heritage</td>
<td>11</td>
</tr>
<tr>
<td>Digital Presentation and Preservation of Cultural and Scientific</td>
<td>9</td>
</tr>
<tr>
<td>2017 9th International Conference on Virtual Worlds and Games for Serious Applications VS Games</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 3 shows that the ACM Journal on Computing and Cultural Heritage is the most cited journal, with a total of 153 times, showing that its research results in this field have received widespread attention and recognition. Multimedia Tools and Applications ranked second, with a total of 79 citations. These journals have made essential contributions and have had an academic influence on applied research on serious games in cultural heritage. They have also actively promoted study in this field.

Table 3: Top 3 Citations of Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM Journal on Computing and Cultural Heritage</td>
<td>153</td>
</tr>
<tr>
<td>Multimedia Tools and Applications</td>
<td>79</td>
</tr>
<tr>
<td>Journal of Computers in Education</td>
<td>57</td>
</tr>
</tbody>
</table>

### 3.3 Publishers and Institutions

Figure 3 presents the top 5 publishers. IEEE (33 articles, 24%), Springer Nature (31 articles, 23%), and the Association for Computing Machinery (22 articles, 16%) are the top three publishers, collectively accounting for over half of all publications, far surpassing other publishers, establishing themselves as market leaders.

Figure 4 shows The University of the Aegean and the Bulgarian Academy of Sciences are the two institutions with the highest output, each publishing 7 articles, and they are also the two institutions with the most robust bibliographic coupling links. It highlights the importance of their research in this field, with deep professional knowledge and research strength. In particular, it has played an important role in international cooperation.

### 3.4 Distribution of Countries or Regions

Figure 5 shows the publication countries and geographical distribution. Scholars from 40 countries have studied the application of serious games in cultural heritage, mainly in Europe, Asia, and the Americas. In terms of number of publications, the top five countries are Greece (1st, 30), Italy (2nd, 28), the United Kingdom (3rd, 13), China (4th, 12) and Spain (5th, 9), with 4 countries belong to Europe, which shows that Europe is the center of research on the application of serious games in cultural heritage. Regarding citation frequency, Italy (1st, 264) ranks as the country with the highest citation frequency, closely followed by Greece (2nd, 188), indicating that research outcomes from Greece and Italy hold significant influence and citation value within the academic community.
Figure 6 shows the co-authorship of countries. Only 20 of the 40 countries have formed a cooperation network. Only 20 of the 40 countries have a collaborative network between authors. In the figure, larger circles indicate stronger linkages, reflecting the level of cooperation and academic exchange between different countries. The two countries with the highest linkage strength are Greece (1st, 15) and Italy (2nd, 9), followed by Spain (3rd, 8), China (4th, 7), and Turkey (4th, 7). It can be observed that cooperation among European and American countries is relatively close. However, China also demonstrates significant performance in international cooperation, engaging to a certain extent with countries such as Greece, the United Kingdom, France, and New Zealand.

3.5 Keyword Co-occurrence Analysis
The researcher conducts co-occurrence analysis in this section using author keywords in VOSviewer. Before analysis, we cleaned the keyword data extracted by the software. We created a Thesaurus file to merge similar words and replace misspelled words, such as “serious game” and “serious games”, “AR” and “augmented reality”, “game-based learning” and “game-based learning”, “digitization” and “digitalization”, “posture identification” and “pose identification”, and so on. We set the minimum number of keyword occurrences to 3 times, and 36 of the 391 keywords met this standard.

These keywords are divided into 5 clusters, represented by different colours in Figure 7. Table 4 shows the information on these 36 keywords. For all keywords, the first number is the frequency of occurrence, and the second number is the total link strength. The largest cluster is the red cluster 1, consisting of 10 keywords. The main keywords include “serious games (82,142)”, “virtual reality (19,54)”, “game design (13,21)”, “user experience (5,16)” etc. This cluster focuses on designing and developing serious games related to cultural heritage, with particular emphasis on the application of virtual reality technology and user experience. Green cluster 2, including 9 keywords, focuses on digital protection and education of cultural heritage. The top three keywords are cultural heritage (71,149), game-based learning (14,28), intangible cultural heritage (8,7), and other noteworthy keywords are interactive learning environments, protection and preservation, and game evaluation.
Blue cluster 3, including 7 keywords, focuses on applying gamification and augmented reality technology in museums. Gamification (13,38), augmented reality (12,30), and museums (7,20) are the main keywords, and the other two keywords worth noting are virtual museum and tourism. Yellow cluster 4, including 6 keywords, focuses on storytelling in cultural heritage serious games, especially interactive digital storytelling. The main keywords are storytelling (12,28) and digital cultural heritage (7,13). Other keywords worthy of attention are immersion and education. Purple cluster 5, including 4 keywords, focuses on the three-dimensional reconstruction of cultural heritage as the research theme. The main keywords are 3D modelling (13,35), 3D virtual reconstructions (3,7), and photogrammetry (3,13).

Figure 8 shows the keyword Cloud Map. A word cloud map allows researchers to intuitively and quickly identify common themes and hot topics in text data in a graphical form (Agbo et al., 2021). It can be seen from the keyword cloud that ten keywords, such as virtual reality, augmented reality, 3D modelling, gamification, game-based learning, storytelling, game design, museums, user experience, and digital cultural heritage, are highlighted, in addition to serious games and cultural heritage. According to keyword co-occurrence analysis and keyword cloud map, the researchers observed that the research focus of serious games in cultural heritage includes: design of serious games, digital protection and education of cultural heritage, virtual reality and augmented reality, gamification in museums and tourism, storytelling, and three-dimensional reconstruction. Figure 9 shows the keyword co-occurrence overlay, which visually presents the development trend of keywords. The color represents the average year in which the keyword appeared, and the more yellow the color is, the more recent the keyword appeared. Researchers found that the latest research hot words are storytelling, tourism, photography, virtual museum, and protection and preservation. It explains that relevant research on the application of serious games in cultural heritage has shifted from early innovative attempts to more professional research, and from the three-dimensional reproduction of historical monuments to presenting the intangible content of cultural heritage through interactive digital storytelling and other methods.
From the laboratory to the public fields such as museums and urban tourism, the focus is on how to use serious games to educate the public and students, so as to enhance the understanding and appreciation of cultural heritage and promote cultural communication.

4. DISCUSSION

This study uses bibliometric methods to analyze the relevant literature on the application of serious games in cultural heritage included in the WOS database as of February 2024. Research shows that the number of relevant publications and the frequency of citations have increased significantly in the past five years, indicating that experts and scholars are increasingly interested in applying serious games to the field of cultural heritage.

The main research areas involved in this study are Computer Science, Education Educational Research, Information Science, Library Science, Arts Humanities, Other Topics, and Engineering. This shows that the research is interdisciplinary, and in the future, researchers can conduct more interdisciplinary research, combining knowledge from computer technology, game design, cultural heritage, and pedagogy to promote innovative applications of serious games in the field of cultural heritage.

The analysis of publication countries and geographical distribution shows that research on the application of serious games in cultural heritage exhibits a Eurocentric geographical feature. This result is relevant to various EU funding schemes (Vlase & Lähdesmäki, 2023). The most significant contributors to academic output are Greece and Italy, the countries with the highest cooperation. In addition, it is worth noting China’s rapid development in this research field. China’s research started late compared to several other significant European and American countries. Still, in recent years, its achievements have been outstanding, and it has become the fourth most significant academic contributor and has established a broad network of cooperation with other countries.
Through the study of 156 articles on the application of serious games in cultural heritage, based on the author's keyword co-occurrence analysis and keyword cloud map, the researchers determined that the current research priorities of serious games in cultural heritage include: Design of serious games, digital conservation and education of cultural heritage, virtual reality and augmented reality, gamification in museums, storytelling and three-dimensional reconstruction. Recent research hotspots include storytelling, tourism, photogrammetry, virtual museum, and protection and preservation.

The results show that the research trends on applying serious games in cultural heritage are from accidental innovative attempts to continuous professional research. As more and more institutions and scholars design serious games for specific cultural heritage, researchers have begun to analyze the game elements, features, and design methods in this type of serious games and study how to maximize users' cognition and experience of cultural heritage in games (Tsita & Satratzemi, 2019; Liu et al., 2022; Camuñas-Garcia et al., 2023). The second is from the three-dimensional reproduction of historical monuments to the presentation of intangible contents of cultural heritage through interactive digital storytelling and other ways. The use of interactive digital storytelling to present cultural heritage is becoming prevalent (Rizvic et al., 2020; Artese et al., 2023) because people are more interested in learning about the stories behind cultural heritage, related historical events, and characters. Combining digital technologies such as virtual reality and augmented reality with storytelling will convey heritage information more effectively (Cozza et al., 2021; Duarte et al., 2021; Hadjiostassou et al., 2023). The third is to shift from the laboratory to social fields such as museums and urban tourism, focusing on how to use serious games to educate the public and students, promote cultural communication, and promote the sustainable development of museums and tourism (Boboc et al., 2022). Virtual museums and virtual tours have become a fashion. More research should be done on how to use digital technologies such as AR, VR, and 3D modelling to provide visitors with a more immersive interactive experience so that they can more intuitively understand cultural relics and attractions and enhance their sense of engagement and attraction (Cosovic & Bricic, 2020; Karageorgiou et al., 2021).

5. CONCLUSION AND LIMITATIONS

This study uses bibliometric analysis methods to provide a panoramic description of the current application status of serious games in cultural heritage and proposes research hot spots and development trends. This lays a foundation for future research to build new knowledge and provides research directions for researchers entering this field. The application of serious games in cultural heritage is becoming more and more widespread and gradually penetrating professional fields. In the future, interdisciplinary research should be further strengthened, and cooperation among stakeholders should be strengthened. Further research should be conducted on the design of serious games in this area, exploring how digital storytelling and gaming tools can be used to communicate cultural heritage messages more effectively, especially about intangible cultural heritage. The educational and social value of serious games in cultural heritage should be further explored. Attention should be paid to how serious games can be used to educate the public, especially young people, to improve their awareness and understanding of cultural heritage and to truly protect and inherit cultural heritage from the connotation level of cultural heritage knowledge.

This study also has certain limitations. The main weakness lies in the collection of sample data. It only considers the English literature related to the application of serious games in cultural heritage in the WOS database. The results of this study may be limited to articles listed within the WOS database, in which references listed in other databases such as SCOPUS, Google Scholars, IEEE and etc. are not covered. Thus, the scopes of source for references could be extended in future research to include more searching databases in order to enhance the depth and comprehensiveness of the study.

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