Research Hotspots and Development Trends of Education Digital Transformation: A Bibliometric Study

Mengji Wang¹, Xiaojiao Chen², Keke Zhu³, Jian Dai⁴

¹²³ College of Educational Science and Technology, Zhejiang University of Technology, Hangzhou, China
⁴¹⁴ 1464340170@qq.com, ² jiojiozjut@163.com, ³ 823893489@qq.com, ⁴ 1602286116@qq.com

Abstract: Education digital transformation provides direction and guidance for education reform in the new era, making it extremely important to understand the main trends in the current development of education digitalization. This study uses VOSviewer and CiteSpace software to conduct quantitative statistics and analysis of relevant literature from the WoS database from 2001 to 2022, including authorship, country of origin, and publication journals. Visual analysis is conducted on high-frequency keyword networks, keyword timeline maps, and visual maps of journals and authors' countries. This study introduces the research hotspots, evolutionary paths, and development trends in the field of education digital transformation. By analyzing highly cited and representative literature in different periods and summarizing the mainstream research hotspots in the field, the study aims to grasp the development trends in the field and present the macroscopic context of education digital transformation since the beginning of the new century.

Keywords: Digital transformation, Education, Bibliometrics, Knowledge graph.

1. Introduction

The rapid development and continuous improvement in the quality of digital technology for education have made digital learning one of the key components of 21st-century education [1]. UNESCO proposed digital learning and transformation at the Education Transformation Summit [2]. In September 2020, the EU issued the "Digital Education Action Plan (2021-2027)”, advocating for two priority development strategies. The first is to promote the development of a high-performance digital education ecosystem, and the second is to enhance digital skills and abilities for digital transformation [3]. The promulgation of many policies reflects the importance attached to digitalization in education at the national level, and has also aroused the attention of many scholars to research on the digital transformation of higher education. However, there is currently a lack of research on the current status, progress, and trends of digital transformation education across all levels of education. Therefore, this paper uses a bibliometric research method to summarize and generalize the research in this field over the past twenty years, quantitatively demonstrating the development path, research hotspots, and evolutionary trends of this research field. Through a knowledge graph, a more comprehensive combing and analysis of the development in this field is made.

2. Research Method and Materials

2.1 Research Methods

This study will use bibliometric methods to systematically, objectively, and comprehensively analyze the research agenda of digital transformation in education from a global perspective. Bibliometrics is a quantitative research method that applies mathematical and statistical methods to analyze data such as the number of documents, publications, and citations to describe and analyze the dynamics and progress of a discipline or research field [4].

This study mainly uses CiteSpace and VOSviewer to create a knowledge graph. VOSviewer uses a probabilistic data normalization method and provides various visualization views in the fields of keywords, co-occurrence, and co-authors, with outstanding features of easy-to-use mapping and visually appealing images [5]. It is mainly used for co-citation analysis of cited references and cited journals in this study. CiteSpace can be used to detect and analyze emerging trends and sudden changes related to the research frontier over time [6]. Timezone maps drawn using CiteSpace are used to depict the changes in the development frontiers and hotspots over time and to determine the focus of research frontiers in specific periods. In educational research, bibliometric research based on CiteSpace and VOSViewer has demonstrated its unique advantages and application value [7-9].

2.2 Research Materials

To ensure the comprehensiveness and authority of the analyzed data, this study selected Web of Science (Core Collection) as the data source, with the index selection of SSCI and SCI-Expanded. The retrieval strategy selected was TS = (("digital transformation" OR "digitalization") AND ("instruct*" OR "education" OR "school" OR "university" OR "college" OR "K12" OR "K-12" OR "elementary" OR "primary education" OR "secondary education" OR "higher education")) covering the time span from January 2001 to December 2022, and the retrieval time ended on December 31, 2022. The document types selected were Articles and Review Articles, and the language was English. 833 literature records were obtained after the search. However, data obtained directly through the retrieval strategy may have some issues such as duplication or inconsistency with the topic, so data pre-processing is necessary before analysis to avoid affecting the results due to data quality issues.

As the research focuses on the key points of digital transformation in education, the included studies are required...
to focus on the concepts of education, digitalization, and development transformation. In the process of manual literature screening, this study also used these criteria as key inclusion standards. After screening each article, a total of 366 valid literature were finally obtained. The 366 papers used in this study were written by 1259 authors from 658 institutions in 74 countries, published in 175 journals, and cited 18,203 cited references from 9,711 journals.

Figure 1 shows the time distribution of research papers on digital transformation in education. Overall, the number of publications in this field has been increasing, especially since 2020 when there was a rapid increase. This is mainly due to the impact of the COVID-19 pandemic in 2020, which led to the large-scale application of online learning technology, accelerating the process of digital transformation in education. At the same time, more and more scholars have started to study the digital transformation of education.

3. Results and Discussion

3.1 Bibliometric Analysis of the Author

By analyzing the authors of the literature, we can identify the representative scholars and core research forces in this field of study. The famous scholar Price (1963) pointed out that in the same subject area, half of the papers are written by a group of high-productivity authors, whose number is approximately equal to the square root of the total number of authors [10].

\[ \sum_{n=1}^{m} n(x) = \sqrt{N} \]

Among them, \( n(x) \) represents the number of authors who have written \( x \) papers, \( I = \) the number of papers of the most productive author in the field (which is known to be 4 through VOSviewer statistics), \( N \) is the total number of authors, and \( m \) is the minimum number of publications for core authors. According to Price’s Law, the minimum number of publications for core authors in a field, \( m = 0.749 \times 1.50 \). Therefore, authors who have published more than 2 papers (including 2 papers) are identified as core authors in this field, totaling 59 core authors with a total of 95 publications, accounting for 26.0% of the total number of publications.

There is a certain gap from the standard of half (50%) proposed by Price, indicating that the research field is still in its developing stage. Table 1 shows the top 5 high-productivity authors in terms of publications, citation counts, and average citation per paper in this field, in order to analyze the representative scholars and research core of this field.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Author</th>
<th>Documents</th>
<th>Citations</th>
<th>Average Citation/Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Altinay, F</td>
<td>4</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>2</td>
<td>Dagli, G</td>
<td>4</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>Abad Segura, E.</td>
<td>3</td>
<td>156</td>
<td>52</td>
</tr>
<tr>
<td>4</td>
<td>González-Zamar, M.D.</td>
<td>3</td>
<td>156</td>
<td>52</td>
</tr>
<tr>
<td>5</td>
<td>Altinay, Z.</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>López-Meneses, E.</td>
<td>3</td>
<td>47</td>
<td>15.67</td>
</tr>
<tr>
<td>7</td>
<td>Landri, P.</td>
<td>3</td>
<td>34</td>
<td>11.33</td>
</tr>
</tbody>
</table>

It can be seen that Altinay and Dagli, who are tied for the highest number of publications, have published a total of 4 papers, but they have very few citations. Abad Segura and González-Zamar have published 3 papers with a high average citation count of 52. From the published articles, Abad Segura and González-Zamar have collaborated on multiple occasions, mainly studying sustainable management of digital transformation in higher education [11], as well as conducting trend analysis across various industries.

3.2 Bibliometric Analysis of the Journal

By analyzing the journals where the literature belongs, it can be found that the papers in this field have been published in a wide range of areas in the past twenty years. In addition to the majority of the journals belonging to the fields of educational technology and computer science, there are also journals in psychology education, medical education, and so on. Table 2 shows the top ten journals in terms of the number of published articles. Among them, the journals with 15 or more articles include Sustainability and Education and Information Technologies, with 51 and 26 articles, respectively. It can be seen that Sustainability has promoted the research progress in this field to some extent, and the high number of articles published in Education and Information Technologies also confirms that the digital transformation of education is an inevitable trend of information technology applied to the education field. From Table 2, it can be seen that the journal with the highest average citation per article is Computers in Human Behavior, which is a top journal with high impact in the field of experimental psychology, and indirectly reflects the interdisciplinary nature of this research field from the perspective of journals.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Source</th>
<th>Publications</th>
<th>Citations</th>
<th>Average Citation/Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sustainability</td>
<td>56</td>
<td>717</td>
<td>12.80</td>
</tr>
<tr>
<td>2</td>
<td>Education and Information Technologies</td>
<td>26</td>
<td>177</td>
<td>6.81</td>
</tr>
<tr>
<td>3</td>
<td>Frontiers in Psychology</td>
<td>12</td>
<td>133</td>
<td>11.08</td>
</tr>
<tr>
<td>4</td>
<td>European Educational Research Journal</td>
<td>8</td>
<td>82</td>
<td>10.25</td>
</tr>
<tr>
<td>5</td>
<td>International Journal of Environmental Research and Public Health</td>
<td>7</td>
<td>72</td>
<td>10.29</td>
</tr>
<tr>
<td>6</td>
<td>Computers in Human Behavior</td>
<td>7</td>
<td>158</td>
<td>22.57</td>
</tr>
<tr>
<td>7</td>
<td>Interactive Learning Environments</td>
<td>6</td>
<td>1</td>
<td>0.17</td>
</tr>
</tbody>
</table>
3.3 Bibliometric Analysis of the Country

In order to understand which countries have made the most prominent contributions in the field of digital education reform, this study analyzed the publication output of 74 countries. First, VOSviewer was used to visualize 30 countries with a publication output of 5 or more articles, and the results are shown in Figure 2. The size of the circular nodes represents the amount of publications, and the connection between nodes represents the strength of the association, with thicker lines indicating a higher number of co-authored publications between two countries. The color of the nodes represents different clusters.

From Figure 2, we can visually understand the main publishing countries and cooperative groups in this field. The United States, Germany, China, and Spain are four countries that not only have a large number of publications, but also have close cooperation and frequent international academic exchanges. The internationalization level of academic research on education digitalization reform is relatively high.

Table 3: Top 5 countries in the Education digital transformation

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Publications</th>
<th>Citations</th>
<th>Average Citation/Publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>61</td>
<td>280</td>
<td>4.59</td>
</tr>
<tr>
<td>2</td>
<td>Germany</td>
<td>49</td>
<td>619</td>
<td>12.63</td>
</tr>
<tr>
<td>3</td>
<td>Spain</td>
<td>48</td>
<td>777</td>
<td>16.19</td>
</tr>
<tr>
<td>4</td>
<td>USA</td>
<td>29</td>
<td>856</td>
<td>29.52</td>
</tr>
<tr>
<td>5</td>
<td>Italy</td>
<td>21</td>
<td>176</td>
<td>8.38</td>
</tr>
</tbody>
</table>

Further analyzing the high-productivity countries in this field, Table 3 presents the top 5 countries in terms of publication volume. Analyzing the data in Table 3, we can see that Chinese scholars have contributed the most research papers in this field (a total of 61 papers published), accounting for 16.7% of the total publication volume in this field, but with relatively fewer citations. The United States had the highest average citation per paper, with 29 papers receiving 856 citations and an average citation of 29.52, indicating that the quality and recognition of papers published by the United States in this field are relatively high.

3.4 Co-occurrence Analysis on Keywords

Keywords, as the core and focus of a paper, can be used to identify research hotspots in a certain scientific field through co-occurrence analysis. Using VOSviewer to draw a co-occurrence map of keywords from 366 articles, key keywords with a frequency of 10 or more were selected for visualization, resulting in 4 clusters, as shown in Figure 3. The larger the circle node in Figure 3, the more times the keyword appears; the node connection represents the association strength, and the thicker the connection, the more times the two keywords appear together in the same article.

After sorting out the specific connotations, node distribution and size of the keywords within the clusters, as well as the structural relationships between the clusters and keywords, four research topics can be identified.
In the red cluster, the research topic is that the purpose of digital transformation in education is to achieve sustainable development. Sustainable development education has been internationally recognized as a key driving force for achieving sustainable development. For example, Sá & Serpa strive to find digital teaching methods and leadership models to improve teaching and achieve sustainable development in education [12]. Sara Calvo studies the role of digital education and online courses in social enterprise development and global sustainability by studying cases of MOOCs [13]. Whether in primary education or higher education, continuous self-innovation is needed. With the development of today’s society, dynamically optimized data algorithms have penetrated into higher education, which has a certain impact on the innovative application ability of various majors [14].

In the green clustering, it can be seen that there is a very close relationship between digitalization and higher education and technology. The research theme of this cluster is the digital transformation of higher education, which is an important component of education as the main social activity for cultivating advanced professionals and personnel. For example, Bygstad proposed that universities should adopt a learner-centered approach to digital transformation, that is, to establish a shared learning space [15]. In addition, digital transformation in education requires the use of technology. The development of online communication technology (ICT) has greatly improved the level of communication between students and teachers in the field of higher education, making a huge contribution to the digital transformation of higher education institutions [16]. The hot research topic in digital transformation is VR/AR technology, which is applied in various fields of education, including but not limited to subject education, medical education, and engineering education.

In the blue clustering, the background of the digital transformation of education is explained. The massive outbreak of the COVID-19 pandemic has impacted various stakeholders in education, including students, teachers, schools, and management systems. This has led to the widespread application of e-learning [17][18], and students, parents, and teachers have reshaped their ideas about education and accepted new forms of learning such as online learning. Among them, because medical education pays more attention to the combination of theory and practice, scholars' research in the field of medical education is more prominent [19].

In the yellow clustering, only the keyword "skill" is mentioned, indicating that the content of the digital transformation of education emphasizes the learning of skills. This includes not only teachers' proficiency in using
information technology skills, but also the skills that students acquire in digital teaching.

3.5 Co-occurrence Analysis on Keywords

This study employs CiteSpace to conduct a high-frequency keyword evolution analysis on literature across different time zones, tracking and observing the dynamic development process of the digital transformation of education. In Figure 4, each background bar in the time zone chart represents a year, and the size of the keyword indicates the frequency of the keyword. The line represents the co-occurrence relationship between the keywords. CiteSpace provides the function of a year ring, and the overall size of the year ring reflects the sum of the frequency of keyword occurrence. The year ring filling color is marked using the time slice of the cited literature. The wider the year ring, the higher the frequency of the keyword studied in the corresponding year. By comparing with the legend in the lower right corner of the image, the research status of the keyword in different years can be obtained.

Figure 4: Evolution on keywords

From Figure 4, the size of the tree rings and the density of their relationship can clearly show that technology, higher education, and digital transformation are the most frequently researched keywords in recent years. Based on the width of each ring’s color, it can be seen that the popularity of technology has been increasing year by year since 2019, while higher education and digital transformation have increased in research frequency in the past two years and have spawned many new related keywords, forming a relatively extensive research subfield.

Analyzing the main audience of the education digital transformation shows that the research focus since 2017 has been on students, while in 2020, research on teachers and universities emerged, indicating the diversification of research objects.

The innovation of technology has opened up new development directions in various fields of education. For example, electronic textbooks are involved in teaching [20], blockchain technology is used for student coordination and work evaluation [21], and AR is used for physical education scholars have also proposed to pay attention to the protection of students’ and teachers’ privacy in digital transformation [23].

4. Conclusion and Prospect

4.1 Conclusion

As an emerging hot topic, digital transformation in education has attracted much attention from various social sectors, and is a constantly evolving research issue. Based on VOSviewer and CiteSpace software, this study analyzed research on digital transformation in education over the past two decades, exploring and analyzing the core authors, high productivity national institutions, key journals, and keyword clusters in this research field. The conclusions drawn from the study are as follows:
1) The author collaboration group in the field of digital transformation in education is still in the process of formation, and a stable core author group has not yet been formed. Journals that publish papers in this field are mainly in the fields of educational technology and computer science, as well as psychology education, medical education, and others. Journals such as Sustainability and Education and Information Technologies are the main driving force behind the development of this field.

2) In this field, Chinese scholars have made the most contributions, but in terms of the average number of citations per article, articles published by American scholars are more recognized in the field.

3) Co-occurrence analysis and clustering analysis of keywords have found that several stable research topics have emerged in this research field, such as digital transformation in higher education and medical education.

4) The evolution analysis of keywords has found that this research field has developed rapidly in the past decade, and both the breadth and depth of the research have been greatly expanded, with a deeper application of technology.

4.2 Limitation and Outlook

Due to certain objective factors, this study also has some limitations. Firstly, the literature analysis software has high standards for data quality and completeness. To ensure these, the study only selected journal articles from the core collections of the Web of Science databases, SSCI and SCI-Expanded, excluding other data, which may result in incomplete data analysis. In addition, due to space limitations, there are still some unexplored topics in this study, such as some technologies related to education digitalization, and the advantages and disadvantages of these technologies for education, which also indicate directions for future research.

As a highly active and cutting-edge issue, the digital transformation of education undoubtedly has great potential for development. Therefore, it is reasonable to believe that with the continued iteration and development of technology, research on the digital transformation of education will have broad prospects. Therefore, this study still has significance and value for further deepening the research.

5. Fund

This paper was supported by the Scientific and Technological Innovation Activity Project (No.G222111110138, G23131110041) and National University Student Innovation and Entrepreneurship Training National Project (No.202210337027, 202210337003).

6. Acknowledgment

The authors would like to express their sincere gratitude to the reviewers and editor for their valuable suggestions, to Chengliang Wang for his careful guidance, to Zhejiang University of Technology for providing places for learning and researching.

References


