

Visual Thinking in Education: A Literature Review and Research Trend Analysis Based on CiteSpace

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Abstract—As the development of educational technology continues and educational reform advances, the role of visual thinking in education is receiving increasing attention. This study offers a thorough review and analysis of the trends in research on visual thinking education, utilizing CiteSpace to expose the current status, main research areas, and crucial terms associated with visual thinking in education. The results highlight that the application of visual thinking in education is chiefly focused on creativity, design, and visual thinking itself. Future research trends are projected to prioritize interdisciplinary integration and application, individual variances, the integration of cutting-edge educational technologies, and the cultivation of outstanding educators. This study provides valuable insights that can contribute to the ongoing encouragement of academic innovation and practical growth in the field of visual thinking education.

Keywords— CiteSpace, visual thinking, education, research trends

I. INTRODUCTION

Visual thinking plays a crucial role in learning and problem-solving across various fields, such as science, mathematics, and language education. However, it has often been neglected in education, leading to a lack of coherence in curriculum design, teaching methods, and learning theories (Mathewson, 1999). In recent years, the educational research community has increasingly focused on visual thinking. This literature review aims to provide an overview of the key studies and research trends in visual thinking in education, with a particular emphasis on using CiteSpace as an analytical tool. Areas of research include mathematics education (Clements, 2014), English education (Huh, 2016), and the impact of specific teaching strategies and tools on the development of visual thinking skills (Kamp et al., 2014; Han et al., 2015; Ivanova, 2020; Lynch, 2021). Furthermore, some researchers have explored the broader implications of visual thinking in education, such as students' higher order creative skills (Genc, 2016) and the cultivation of observational abilities in educational settings (Demir et al., 2021). By employing CiteSpace for a systematic review and analysis of research trends, this paper aims to offer a comprehensive overview of the field, identifying key themes and directions for future research.

II. OBJECTIVE

The purpose of this study is to comprehensively review the literature on the application of visual thinking in education, showcasing the current status, major research areas, keywords, and trends of visual thinking education research, providing valuable references for further educational practice and research. We will use CiteSpace, a knowledge mapping analysis tool, to visualize a large body of literature, aiming to present scholars the overall landscape and evolutionary trends of the visual thinking education research field, thus promoting academic innovation and practical development in the area.

III. METHODS

To collect literature related to the application of visual thinking in education, we chose the internationally renowned academic database, Web of Science, for searching. The advantage of using Web of Science lies in its coverage of numerous disciplinary fields and international high-quality papers, providing abundant data sources for research. Meanwhile, the citation information provided by Web of Science aids us in conducting CiteSpace analysis. We used keywords including "visual thinking," "education," "visualization," and relevant subject terms combined to search within a certain time range. During the data collection process, we ensured that the collected literature was closely related to the research achievements in the field of visual thinking education.

IV. RESULTS

A. Basic Information Analysis

To gain a deeper understanding of the development history and current status of visual thinking research, we consulted related literature using the Web of Science database. Changes in the number of published papers can reflect the development of a field and its future research trends. As shown in Figure 1, a total of 525 related papers were published in the past twenty years (1997-2022), showing a generally steady growth trend.

Between 1997 and 2009, the number of published papers was relatively low, indicating that during this stage, visual thinking research was in its infancy. The low number of publications can be attributed to limitations in research methods and a lack of high-quality related literature at the

time. However, with the continuous enrichment and expansion of research methods and content, the number of publications has shown substantial growth since 2010, displaying a rapidly rising trend. Particularly in 2019, the annual publication volume peaked at 57 papers, markedly indicating that the visual thinking research field is currently in a stable development phase.

In the past three years, the number of papers published annually has consistently remained above 40, further confirming that the field is in a stable development phase. In terms of overall trends, the visual thinking research field has gradually shifted from its initial stage to a stable development phase, laying a solid foundation for further in-depth study and promoting the advancement of the field.

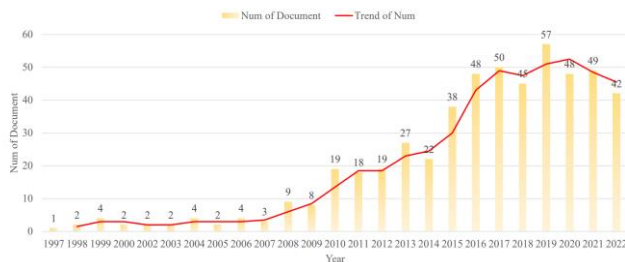


Fig. 1. Author's chart.

B. Keyword Analysis

Co-occurrence analysis of keywords is an essential method for studying hotspots and research trends in academic fields. By extracting keywords, abstracts, and other bibliographical information from the literature and conducting statistical analysis, we can form an intuitive knowledge map. This study analyzes the co-occurrence of author keywords in the field of applying visual thinking in education, discovering 310 high-frequency keywords that form 336 connections. By examining these high-frequency keywords, we can understand the recent hotspots and potential research trends of the field.

As shown in Figure 2, the nodes and text size in the keyword co-occurrence map represent the frequency of each keyword's occurrence. The connections between nodes indicate the relationships established during different periods, with the thickness and density of the lines indicating the intensity of keyword co-occurrence. Observing Figure 2, we find that "education" occupies a central position in keyword co-occurrence and has the highest frequency, while "design" and "creativity" also have relatively high co-occurrence frequencies.

Various research hotspots from different periods can be observed in the keyword co-occurrence map. In the early research stage, focus is centered on directions such as "spatial ability," "education," "design," and "design education," reflecting the main research directions of visual thinking and its application in education. In recent years, keywords in the co-occurrence map like "design-based learning," "participatory design," "art design," and "affective learning" suggest that future research in visual thinking education will focus on design-based learning, participatory design, art design, and affective learning.

Keyword co-occurrence analysis allows for a more in-depth understanding of research hotspots and development trends in the field of visual thinking in education. This is of great significance for further academic research and promoting the development of related fields. Moreover, this analysis method can be generalized and applied to other academic fields to reveal current research status and future development directions.

Keywords with high betweenness centrality play a critical bridging role in co-occurrence networks and typically have closer connections with other hotspot keywords. In this study, keywords such as "education," "creativity," and "pedagogy" have high betweenness centrality in the co-occurrence network, acting as a link for communication and interaction between different themes in the research field, thereby exerting a positive impact on the inter-citation relationships between literature items.

Keywords with high betweenness centrality emphasize their importance in research fields. These keywords likely correspond to core topics in the current research field, reflecting the research interests of scholars.

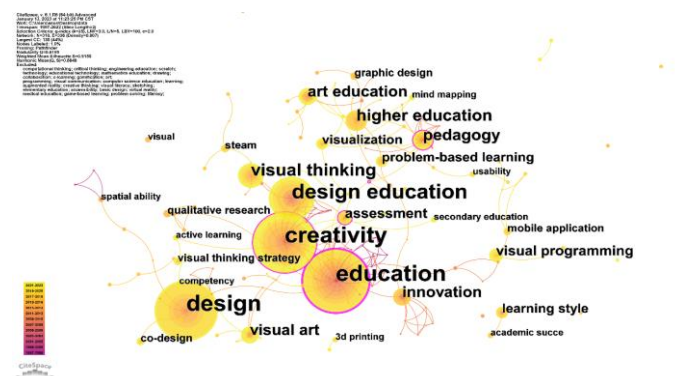


Fig. 2. Keyword clustering.

TABLE I. Top 10 keywords by centrality.

S. No.	Keywords	Frequency	Betweenness Centrality
1	education	33	0.28
2	assessment	7	0.14
3	creativity	32	0.13
4	pedagogy	10	0.11
5	art & design	1	0.1
6	classification	1	0.08
7	problem-solving	2	0.06
8	digital tool	1	0.05
9	design	32	0.05
10	artificial intelligence	1	0.04

Thus, hotspot topics reveal the focus of scholars in specific fields and the main issues discussed in a certain period. Keywords, as the core part of academic papers, can summarize the main points of papers and have important value in the discussion of hot issues in research fields. In this paper, CiteSpace software and LLR (Log-Likelihood Ratio) algorithm are used to cluster the co-occurrence of keywords, so as to intuitively present research hotspot topics.

Figure 3 shows the keyword clustering view, where the colored blocks represent clustering areas, including corresponding clustering keywords. The number of nodes $N =$

310, the number of edges $E = 249$, and the network density $Density = 0.0052$. The module value Q is related to the density of nodes, and the larger the Q value, the better the clustering effect and the more conducive to scientific analysis. The average silhouette value S measures the homogeneity of clustering, and the larger the S value, the higher the network homogeneity, and the higher the credibility of clustering results.

As can be seen from Figure 3, the Q value is 0.8044, indicating excellent clustering effect of the network structure; meanwhile, the S value is 0.7877, confirming higher clustering homogeneity, making different clustering distinctions more explicit. A total of 7 major clusters are shown in the figure, led by "education," "higher education," and "design." The average year distribution of the top five clusters ranges between 2010 and 2015, implying that these research hotspots gradually formed during this period.

As shown in Table 2, the largest cluster is "education," which began in 2010 and covers 29 keywords, such as education, urban design, youth, mobile applications, and visual design. Based on the system-generated clustering report, we found the most relevant literature to this cluster is Solecki, IDS(2019) "Codemaster UI design - App Inventor: A rubric for the assessment of the interface design of Android apps developed with App Inventor."

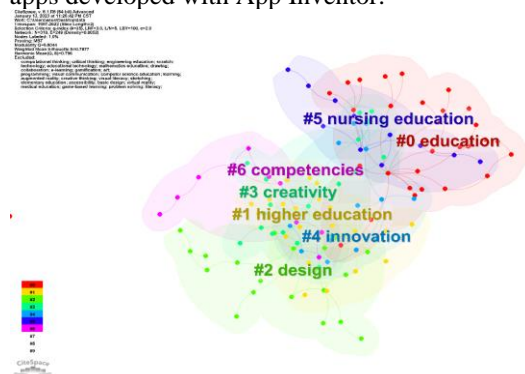


Fig 3: Keyword Clustering Map.

TABLE II. Key Authors and Collaboration Network Analysis.

S. No.	Author	Year	Publication Count	Connectivity
1	Su, Yu-Sheng	2021	4	3
2	Admiraal, Wilfried	2015	3	4
3	Tsai, Meng-Jung	2012	3	3
4	Dominguez somonte, M	2016	3	2
5	Espinosa escudero, M M	2016	3	2
6	Martin erro, A	2016	3	2
7	Basu, Satabdi	2015	2	14
8	Biswas, Gautam	2015	2	14
9	Arnab, Sylvester	2015	2	10
10	Basogain, Xabier	2016	2	8

To explore the development trends in the research field, we need to pay attention to these keyword clusters and further mine them. Research with high homogeneity and clustering effect will systematically present the application of visual thinking in the field of education, uncover significant research issues, and provide useful references for future academic research. Similarly, analyzing the changes in keyword clustering contributes to determining the dynamic changes in

the field, predicting emerging trends, and laying the groundwork for targeted research deployment.

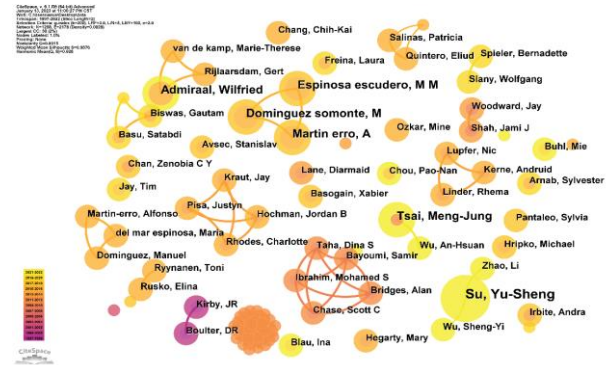


Fig 4: Collaborative Network Knowledge Graph.

Figure 4 reveals the author collaboration network in the field of visual thinking applied in education. From the figure, it can be seen that the entire network consists of 1,258 nodes and 2,178 edges, with a network density of 0.0028. A higher network density usually indicates closer collaboration within the academic field, which is conducive to the dissemination of research resources and information among researchers. However, as seen in Figure 4, the collaboration relationships among authors in this field are not yet sufficiently close.

Upon further analysis of Figure 4, we find no prominent author collaboration network. The collaboration groups of major authors are relatively small in size, mostly consisting of small teams of about three people, and they are distributed across the entire network. This situation may hinder communication and collaboration between researchers, making it unfavorable for the collision of innovative thinking and the accumulation of research results.

In terms of the number of papers published, there are few authors with relatively high publication volumes; only six authors have published three or more papers. This indicates that the total volume of papers published in this field is relatively low, making it difficult to identify core members in the research field, which in turn affects the formation and development of the cooperation network.

Combining Figure 4 and Table 2, we can further analyze the current development of research on the application of visual thinking in education. The collaboration relationships between the main authors are weak, implying that a close and mature collaboration network has not yet been established in this field. To promote the development of the domain, it is suggested to actively seek cooperation partners and opportunities, build cooperation platforms, and realize resource sharing.

Furthermore, referring to the citation of related authors' literature to determine the sources of foundational literature will help grasp key issues and significant research results, providing targeted expansion for follow-up studies. Tracking influential authors and their collaboration networks can reveal development trends and patterns in the research field, offering more references for subsequent academic research and cooperation.

V. CONCLUSION

This article presents a literature review and analysis based on CiteSpace, aiming to investigate the application of visual thinking in education, offering a comprehensive understanding of the research hotspots, prominent themes, author collaboration networks, and development trends in this realm. The analysis reveals that although certain achievements have been made in utilizing visual thinking in education, challenges and inadequacies still exist. In future research endeavors, it is advisable to focus on these keywords possessing high betweenness centrality and initiate more in-depth discussions and exploration around them. This approach will contribute to enhancing research quality and impact while providing valuable insights and guidance for academic exchange and cooperation in related disciplines.

In conclusion, the consistent exploration and validation of visual thinking integration in education have demonstrated its effectiveness across a diverse range of fields, such as graduate education courses, art education, medical education, and higher mathematics. The implementation of visual thinking routines, as exemplified by those at the American University in Dubai (Gholam, 2019), has been proven to enhance students' comprehension and engagement in the learning process. Similarly, the successful design and implementation of visual communication media have been observed in various educational institutions, including STMIK PalComTech and PalComTech Polytechnic (Syahrul, 2019).

Ulger (2019) emphasized the significant role of art education in fostering creative thinking, while Mukunda et al. (2019) illustrated the benefits of integrating humanities and visual arts training in medical education, citing improvements in clinical skills and professional development. Additionally, the efficacy of visual education approaches was investigated in the ESP class at Omsk State Agrarian University (Kulamikhina et al., 2020).

Ivanova (2020) demonstrated the effectiveness of SMART-lectures in teaching higher mathematics, contributing to the development of visual thinking and enhancement of teaching efficiency. Moreover, Tarasova et al. (2020) explored the educational potential of fine arts in cultivating visual thinking and shaping the worldview of university students. Demir et al. (2021) also supported the use of visual thinking in medical education, providing preliminary reflection results from a visual thinking course at the Faculty of Medicine, Izmir University of Economics.

Lynch (2021) investigated Visual Thinking Strategies (VTS) as a promising methodology for boosting student engagement and critical thinking skills. Choi et al. (2022) further emphasized the applicability of visual thinking in various educational settings through a study conducted in an urban nursing college in Seoul, Korea.

In conclusion, the consistent exploration and validation of visual thinking integration in education have demonstrated its effectiveness across a diverse range of fields. However, as the adoption of visual thinking continues to expand, several future challenges and recommendations emerge that warrant consideration by researchers and educators alike.

First, while visual thinking has shown promising results in various educational settings, there is a need for more comprehensive and longitudinal studies to better understand its long-term impact on student learning outcomes and retention. This will enable a more robust evaluation of the effectiveness of visual thinking approaches and help identify areas for improvement.

Second, the integration of visual thinking in education should be tailored to the unique needs and preferences of different learner populations. As cultural, linguistic, and cognitive factors may influence the way students perceive and process visual information, future research should investigate the effectiveness of visual thinking strategies across diverse learner groups to ensure that these approaches are inclusive and equitable.

Third, the rapid advancement of digital technologies and media presents both opportunities and challenges for the integration of visual thinking in education. Educators should stay abreast of emerging technological innovations and consider how these tools can be leveraged to enhance visual thinking instruction. At the same time, potential barriers to technology access and digital literacy should be addressed to ensure that all students can benefit from these advancements.

Finally, the development of innovative teaching methodologies incorporating visual thinking, such as VTS, should be pursued and refined in collaboration with interdisciplinary experts. This will help bridge the gap between theory and practice, ensuring that visual thinking strategies are grounded in evidence-based research and effectively implemented in the classroom.

Through the literature review and analysis utilizing CiteSpace, a lucid apprehension of the research hotspots and developmental tendencies within the field of visual thinking in education can be attained. Concentrating on and conducting meticulous research on these keywords displaying high betweenness centrality, in conjunction with integrating authentic educational scenarios and modern technological advancements, will foster research innovation and ameliorate teaching practices in the domain of visual thinking in education. By doing so, a substantial contribution can be made to the all-encompassing development of education.

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