Current Status and Trends of Research in the Field of Visual Thinking - A Visual Analysis of Literature Based on Citespace

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Abstract. As an important component of intelligent design, visual thinking is the main ability and quality of our creative design, the logical training of visual thinking is the means to make design communication more efficient, and the accuracy of visual language is the necessary quality to accurately convey information. This study adopts a visual econometric analysis method, selecting relevant literature from the CNKI citation index database from January 1, 2000, to July 28, 2022, as the database and conducting a graph analysis of visual thinking research results with the help of CiteSpace information visualization software. The results show that: (1) The number of published papers has increased yearly, especially after 2015, experiencing three stages of steady growth, rapid growth, and ups and downs. (2) Researchers have a strong sense of cooperation, forming some cooperative teams among countries, but less cooperation among teams; (3) The research themes and perspectives of this paper are broad, covering the fields of economy, culture, science, and technology, education, art, sports, and health; (4) Research hotspots are mainly reflected in memory, education, art and so on. The research object has undergone the evolution and development process of human-centered, teaching-centered, and culture-centered.

Keywords: visual thinking, visualization, knowledge graph, Citespace

1 Introduction

Visual thinking, also known as 'visual thinking,' first appeared in the book' Visual Thinking' by the educationalist Rudolf Arnheim 1 Although 'visual thinking is no longer a brand new term, there is still a need to dig deeper and broaden the objectives in the actual study and use of visual thinking 3. With the development of information technology, the study of visual thinking has become more than just the study of "behavior, life, intelligence, the brain" and other independent thinking. It is gradually moving towards education, culture, and other disciplines. However, the current status and trends of visual thinking research have not been studied by scholars. The present

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research on knowledge graph and visualization in the field of visual thinking has not found any research on the application of visualization software to visual thinking. This study will analyze the volume of publications, author collaboration, transnational collaboration, keyword co-occurrence, keyword time zone graph 12, etc. The visual knowledge graph of visual thinking will directly influence and promote the development trend of visual thinking. Therefore, collating and summarizing the current state of research on visual thinking, sorting out the evolutionary process of visual thinking, revealing the future trends of visual thinking in major fields, and providing theoretical visualization innovations, methodological innovations, and practical approaches for subsequent scientific research on the future development of visual thinking in other areas 9. This paper attempts to analyze the latest progress in conjunction with scientific measurement methods and quantitative analysis from the perspective of knowledge graphics, the current status, development, and trends of multi-style linkage research to provide more informative suggestions and insights for interested researchers 10 .

2 Research Design

2.1 Research Methodology

The CiteSpace information visualization software is developed based on JAVA. Applications that track research hotspots and trends in the field in a multifaceted, time-phased, dynamic visual language of the vast literature data of the knowledge domain. Through keyword search and co-occurrence analysis, author collaboration network analysis 4, transnational power distribution graphs, and time zone views, the current research status, development history, hot topics, and evolutionary trends of the domain of visual thinking are presented through quantitative visualization to reveal the complex relationships, structures, intersections, evolution and derivation between knowledge elements and knowledge communities 6, to obtain the accumulated knowledge points of visual thinking in a specific domain.

2.2 Data acquisition

The term "Visual Thinking" was used in this study after several searches and experiments. The CNKI database was chosen as the data source 8, and the search formula was 'Visual thinking. To assess the results of the research conducted within the collaborative framework as comprehensively as possible, the period was restricted from January 1, 2000, to July 28, 2022, and the search period was July 28, 2022. To ensure the completeness and accuracy of the sample data, the search was restricted by ticking "Thesis" and "Review paper," adding a search restriction in the "Title" field to the retrieved literature and limiting the search to the search string of "journal call for papers" and "report articles" was restricted, and English was chosen as the language.

3 Research progress and trends in visual thinking

3.1 Annual distribution of the number of publications in the field of visual thinking

The number and time distribution of publications can reflect the dynamic evolution of the field to a certain extent. Since 2022 has not yet ended, 2022 is not a reference year when exploring the number of publications, with a valid number of 369 from 2000 to 2021. This value also indicates that visual thinking is a blue ocean research area. According to the year distribution of visual thinking research publications in the CNKI database (Figure 1), it can be seen that the overall annual number of publications in visual thinking research has shown an overall increasing trend over time.

In the period 2002-2006, the overall number of publications showed a flat growth trend, with a small number of studies overall, only 41; between 2007-2017, the overall state of adjustment, in this period the number of publications grew rapidly including the growth of 143% from 2015 to 2017, indicating that at this time the research on visual thinking is gradually becoming a boom; 2018-2021 The number of articles published in the region of the relevant title has fluctuated considerably, but the total number of articles published is high, with a total of 150 articles, with an average of 38 articles published per year, and reaching a maximum of 43 articles in 2019 and close to the peak in 2020.

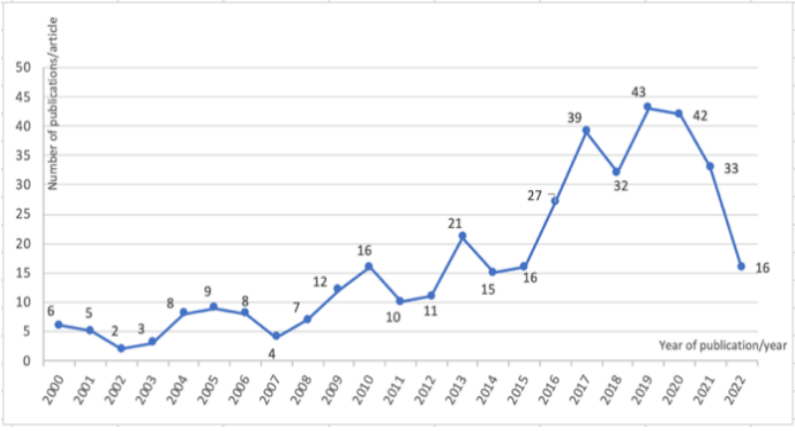

Fig. 1. Distribution of literature in the field of serving visual thinking research, 2000-2022

3.2 Distribution of co-authorship networks

A co-occurrence graph of authors identifies the core authors of a discipline or field and the strength of their collaboration and cross-citation relationships 7. In contrast, scientific collaboration is considered to exist when different authors, institutions, or countries are present in a single paper. The nodes presented on the image indicate the author of the paper, with the larger radius of the author's node indicating a larger volume of

publications, and the darker the color of the link indicating the earlier the collaboration, the lighter the color of the link indicating that the collaboration was established in more recent years 11 According to the table of visual thinking studies (Figure 2),the two authors with the highest number of articles are Z LES and M LES, with five articles each. According to the formula $M \approx 0.749 (Nmax1/2)$ proposed by the famous American bibliographer Mr. Price, where M is the minimum number of articles to satisfy the core authors, it can be seen that $M \approx 2.247$, indicating that authors with ≥ 3 articles can be called the core authors of the discipline 10 according to the data in Figure 1, the total number of articles published by the core authors is 22, accounting for about 5% of the total, indicating that the research of visual thinking .According to Figure 1, the total number of core authors is 22, which is about 5% of the total, indicating that the research on visual thinking has yet to be developed, which is an area with great value. The distribution of links from the network of co-authorship graph of publications (Figure 3) shows that two authors are the most closely connected and have been collaborating for the longest time; two other larger groups of collaborators are ADAM RIZZO, HORACE M DELISSER, SUZANNAH NIEPOLD, BARBARA BASSETT, who published in 2019, and NAZANIN MOGHBELI's research team. In 2021 HARUTO TAKAGISHI, HIROTAKA KAKIZAKI, CHIAKI ISHIGURO, ETSUKO KATO, YUKI SATO, HIROYUKI OKADA, YUKO ABE, AI TAKAHASHI form the group of research authors. At the same time, we can also notice a dramatic increase in the number of individual research author group members over time, which implies a growing depth of research in visual thinking. However, fewer links between collaborative groups of authors and clusters have been established. Overall, there is a relatively strong sense of collaboration in visual thinking research, and several more stable research collaboration teams have been formed. However, there is still a need to strengthen collaboration between teams.

Number of CNKI publications			
COUNT	YEAR	AUTHOR	CENTRALITY
5	2003	Z LES	0
5	2003	M LES	0
3	2020	HOPE TORRENTS	0
3	2016	MARGARET MOORMAN	0
3	2012	JAMI J SHAH	0
3	2012	JAY WOODWARD	0
2	2019	ADAM RIZZO	0
2	2021	HARUTO TAKAGISHI	0
2	2021	HIROTAKA KAKIZAKI	0
2	2019	ANTONELLA POCE	0
2	2011	DIANA BECKMANNMENDEZ	0
2	2021	CHIAKI ISHIGURO	0
2	2013	FELIX T HONG	0
2	2019	HORACE M DELISSER	0
2	2020	GRETA MITZOVAVLADINOV	0
2	2021	ETSUKO KATO	0
2	2019	ALMUDENA FERNANDEZFONTECHA	0
2	2019	SUZANNAH NIEPOLD	0
2	2015	MARVA CAPPELLO	0
2	2021	YUKI SATO	0
2	2021	HIROYUKI OKADA	0
2	2019	BARBARA BASSETT	0
2	2019	NAZANIN MOGHBELI	0
2	2016	DESIREE HENSEL	0
2	2011	CRAIG M KLUGMAN	0
2	2021	YUKO ABE	0
2	2021	AI TAKAHASHI	0

Fig. 2. CNKI Statistics of authors of visual thinking research articles

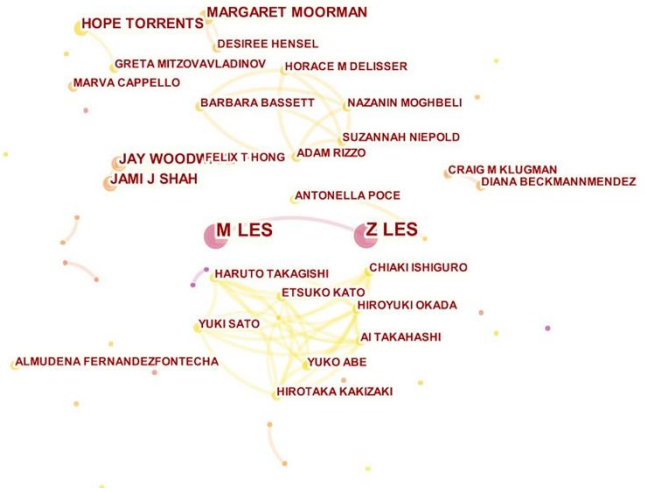

Fig. 3. Collaborative Authorship Network for Visual Thinking Articles

3.3 Distribution of international collaborative research efforts

According to the list of the main international collaborative research forces (Figure 4), the analysis of the main countries where the authors of the articles are located, it is possible to understand that the current core international research field is currently among the top three contributors to the number of articles published in the discipline from the United States, Australia, and the United Kingdom. The US has the highest number of publications, with 67, accounting for 71% of the total number of publications from the top three countries and approximately 43% of the major publishers, indicating that the US is the core force in visual thinking research. Australia has twice as many articles as the UK. However, the top three countries have the highest centrality in Australia (0.05), and the US is the same as the UK (0.03). These research centers have greatly contributed to their development in visual thinking research.

These data reflect the high level of academic inquiry and openness in the US, Australia, and the UK, with Australian papers in visual thinking research more valuable to the discipline in all three countries. The visualization of international inter-collaboration derived from the CiteSpace software analysis (Figure 5) shows that the distribution of research power in international collaboration is mainly in international research teams led by Australia, the UK, and Spain. Australia has the largest number of linking lines and a web-like shuttle with other countries, indicating that it has the largest number of collaborating countries, including the UK, Spain, Portugal, and Singapore. The USA, on the other hand, has the largest diameter of nodes but does not cooperate much with the countries it works with and shows a more homogeneous radial shape. It can also be seen that the US and Australia have been collaborating on research for the longest time.

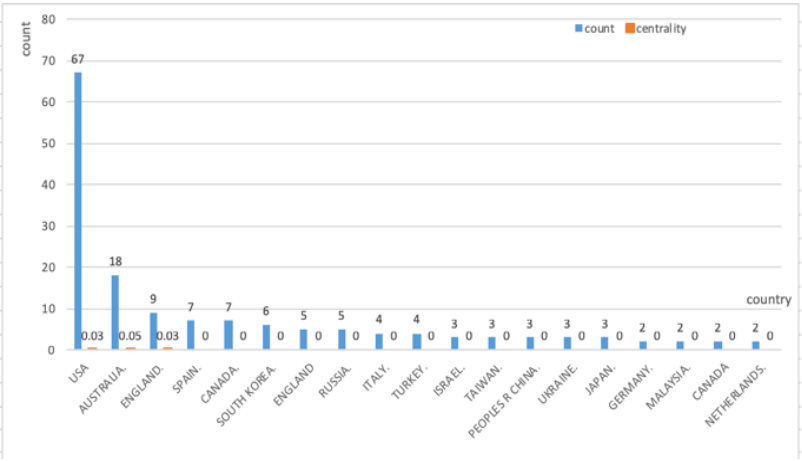

Fig. 4. List of major international collaborative research forces

Fig. 5. Distribution of international collaborative research efforts

3.4 Keyword analysis

Two dimensions are considered: keyword co-occurrence and keyword time zone.

(1) Frequency and centrality of keyword co-occurrence to obtain the relationship between the various topics in the discipline represented by each literature, the keywords are a distillation of the research content. They are the core and essence of the paper. Through the cooccurrence analysis of keywords, it is clear that the distribution of high-frequency keywords within this research area 2 is as follows (Figure 6) CNKI visual thinking research keywords and centrality word list found that the top-ranked keywords are: art, education, model, student, skill, visual thinking strategy. The highest number of art searches, with 18, indicates that visual thinking is more relevant in art. At the same time, education, model, and student also account for a comparable proportion, with the first four accounting for 35% of the total searches. Another statistic is centrality, with the highest being EDUCATION (0.46), FRAMEWORK (0.38), MEMORY (0.37), ART (0.31), and REPRESENTATION (0.29). Of these, education and art lead the rankings for co-occurrence and centrality of keywords, indicating that visual thinking is more intensively studied in education and art. Although visual thinking strategy has a high frequency, its performance in centrality is 0, which means that visual thinking strategy has gradually become a research hotspot since 2014. However, the research results are not outstanding, and there have been no significant breakthroughs yet.

Keywords co-occurrence distribution							
NO.	keywords	count	year	NO.	Central keywords	centrality	year
1	art	18	2014	1	education	0.46	2011
2	education	13	2011	2	framework	0.38	2017
3	model	11	2003	3	memory	0.37	2004
4	student	11	2016	4	art	0.31	2014
5	skill	8	2014	5	representation	0.29	2004
6	visual thinking strategy	8	2014	6	model	0.27	2003
7	recognition	6	2003	7	perception	0.25	2005
8	representation	6	2004	8	knowledge	0.23	2016
9	enhance	6	2014	9	brain	0.19	2004
10	design	5	2009	10	awareness	0.17	2017
11	medical student	5	2011	11	design	0.15	2009
12	perception	5	2005	12	medical student	0.13	2011
13	memory	4	2004	13	behavior	0.12	2000
14	knowledge	4	2016	14	autism	0.09	2000
15	framework	4	2017	15	student	0.09	2016
16	impact	4	2015	16	enhance	0.09	2014
17	awareness	3	2017	17	creativity	0.08	2012
18	system	3	2002	18	observational skill	0.06	2013
19	creativity	3	2012	19	information	0.06	2014
20	brain	3	2004	20	language	0.04	2017
21	language	3	2017	21	impact	0.03	2015
22	observational skill	3	2013	22	skill	0.01	2014
23	imagery	3	2000	23	imagery	0.01	2000
24	behavior	2	2000	24	visual thinking strategy	0	2014
25	care	2	2011	25	recognition	0	2003
26	art museum	2	2014	26	system	0	2002
27	autism	2	2000	27	care	0	2011
28	information	2	2014	28	art museum	0	2014

Fig. 6. CNKI visual thinking research keyword

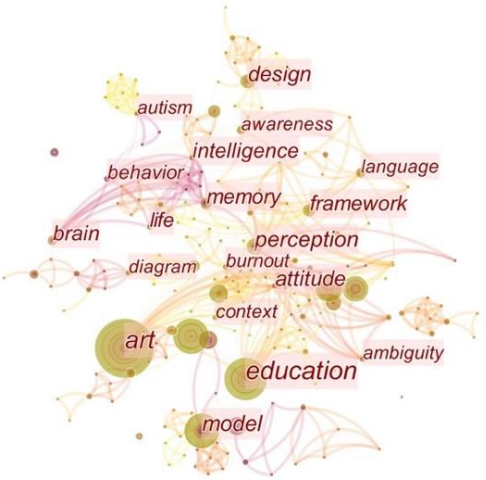

Fig. 7. Cooccurrence graph of visual thinking research keywords

Figure 7 shows the visualization of the data collected by CiteSpace in terms of keyword co-occurrence. The larger the keyword node, the higher the frequency of occurrence.

The figure shows that there is also a close connection between these nodes, indicating that interdisciplinary research is widely used in visual thinking. In addition, the color of the lines represents the flow of knowledge, with lighter colors indicating a later appearance, most likely a new flow of knowledge from a particular phase of research in visual thinking. It is easy to see from the diagram that around the keywords with larger nodes, the lighter color of the lines are framework, education, and life and art have spread out in lighter colors on top of the original darker lines, indicating that these areas are being looked at and researched again.

(2) Time zone analysis of keywords

In CiteSpace, the knowledge graph shown in Figure 8 was obtained when the time zone view was selected. The time zone view is another view that focuses on representing the evolution of knowledge in a temporal dimension and can clearly show the updates and interactions of the literature 5. According to the analysis of the time zone graph of visual thinking research keywords, the general lineage of the evolution of hotspots in visual thinking research can be divided into three phases.

The first stage is the basic research stage of visual thinking. This is also the nascent stage of visual thinking, where the focus is more on "thinking" and "natural human" is the main object of research. "This is the first stage of visual thinking.

The second stage is the exploratory stage of research into the teaching of visual thinking. The most obvious ones are modeling, design, and attitude. At the same time, along with the vigorous national promotion of education, more and more scholars began to pay attention to the importance of teaching philosophy, training objectives, teaching models, methods, etc. for the cultivation of talents, and try to combine visual thinking with the theory of education.

The third stage is the stage of integration of visual thinking culture research. This period began in 2010 with the proliferation of keywords such as art, education, framework, context, etc., and became the current frontier of visual thinking research. The research connotation and extension of this phase are gradually enriched, and the focus of research begins to shift from the macro perspective of "thinking" to the micro perspective of the "visual" act of art, and refine and practice the "human-centered" basic concept of cultural research.

The basic concept of "human-centredness" in cultural studies was refined and implemented.

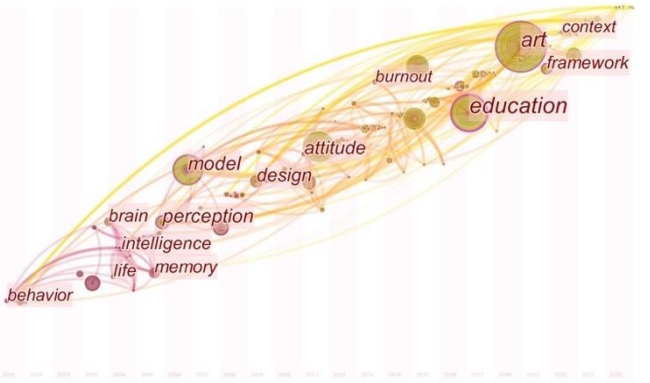

Fig. 8. visual thinking research keyword time zone graph

4 Research Conclusions

In this paper, through a knowledge graph analysis of the annual number of articles, author collaboration, keyword co-occurrence, and keyword time zone distribution of 85 core journal articles in the field of visual thinking research in the CNKI database over the past 20 years, the following conclusions can be drawn. It is found that the research in this field has progressed more significantly and has resulted in a solid body of classics. These have important implications for visual thinking research. This is reflected in the following areas.

1. the overall number of articles published in the year has shown a significant increase, reflecting the side that there is still more research space in visual thinking. However, the overall number of studies is relatively small, and obvious research gaps still need to be filled. Future development should focus on improving the quality of the papers, aiming to produce important papers with "inflection" or "turning point" significance.

2. The wide and open collaboration of authors is conducive to integrating different academic resources, innovation, and the wide dissemination of research results, as well as to the future diversification of the discipline. In addition to the existing collaborative group of authors, other fragmented publications must be further collaborated to establish new connections.

3. The centrality knowledge graph reveals that most of the academically influential scholars in the field of visual thinking research are concentrated in Australia, indicating that Australia has a significant level of academic influence in the field of visual thinking research. Therefore, there is an urgent need to add strong transnational and interdisciplinary partnerships between other independent publishers, which will not only facilitate the output and depth of research but also promote the progress of scientific research.

4. The object of visual thinking research has evolved from being human-centered, pedagogically-centered, and culturally centered. The 'Art' theme is the core of the study,

with the highest frequency and centrality of keywords, and it involves a variety of industries such as culture, technology, education, and art. It is also found that the object of visual thinking research has emerged as a combination of macro and micro, theory and practice. The subsequent visual thinking research should focus on the transformation process from experience to science and theory to practice to actively carry out empirical research while strengthening the weight of visual thinking practice in the cultural and educational industries.

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