

# A Bibliometric Analysis of Chinese and International K-12 Engineering Design Research Using CiteSpace and VOSviewer

Kangkang Luo<sup>1\*</sup>, Salmiza Saleh<sup>1</sup>

<sup>1</sup> School of Educational Studies, University of Sains Malaysia, 11800 USM, Penang, Malaysia

\*Corresponding Author: [kangk12020@student.usm.my](mailto:kangk12020@student.usm.my)

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**Abstract:** *This study aimed to identify the current state of research and gaps of K-12 engineering design research between Chinese and international studies. This study employed CiteSpace and VOSviewer to conduct a bibliometric analysis of K-12 engineering design research, utilizing 86 publications from the China National Knowledge Infrastructure and 170 from the Web of Science Core Collection spanning the period from 2010 to 2024. The analysis revealed three key findings: (a) Chinese and international publications on engineering design grew after 2016 and 2014, respectively, but declined sharply in 2020 and 2022 before rebounding; (b) The U.S. led international research, with strong funding support and collaborative networks centered around Purdue University, while Chinese scholars produced fewer publications, had limited funding, and minimal collaboration; (c) Chinese research focused on curriculum development and conceptualization within STEM, whereas international research emphasized empirical studies on engineering design's impact on student learning and teacher development. This study highlights the need for Chinese research to expand beyond curriculum development and conceptualization, emphasizing empirical investigations into teaching-related factors such as teacher quality and instructional resources, alongside enhanced policy support and collaborative research efforts.*

**Keywords:** bibliometric analysis, comparative analysis, K-12 engineering design, CiteSpace, VOSviewer

## 1. Introduction

Cultivating talent with a strong foundation in science, technology, engineering, and mathematics (STEM) is considered a key driver of economic growth for nations worldwide (Kulakoglu & Kondakci, 2022). As a critical component of STEM, engineering education has garnered significant attention in K-12 education since the introduction of STEM education (Bybee, 2010; Arık & Topçu, 2020). Engineering design, an essential of engineering discipline, is widely recognized as a "catalyst" for integrating science, technology, engineering, and mathematics disciplines to empower students to address societal challenges (NRC, 2013; Moore et al., 2014). Thus, its importance has also been increasingly recognized in K-12 education, particularly following the adoption of the Next Generation Science Standards (NGSS) (Chabalengula & Mumba, 2017; Moore et al., 2015), which has driven engineering design to become a focal point of global research, with studies investigating its potential to enhance students' understanding of core scientific concepts, foster creativity, and cultivate collaboration and communication skills (National Academies of Sciences, Engineering, and Medicine, 2019; Ali & Tse, 2023). Many of these studies further focused on the professional

development of teachers to implement engineering design (e.g., Guzey et al., 2016; Maeng et al., 2017) and its integration with science education (e.g., NRC, 2009).

With the growing international emphasis on engineering design, its integration in China K-12 education has gradually gained attention over the past decade, driven by educational reforms such as the release of Compulsory Primary School Science Education Curriculum Standards (MOE, 2017). Chinese studies primarily emphasized defining engineering design within the K-12 context, exploring implementation pathways, and developing localized curriculum resources (Xie & Li, 2017), reflecting an early stage of conceptual exploration and localization, with a focus on aligning engineering design with the national curriculum and educational goals (Shi et al., 2023). However, despite these efforts, Chinese research remains largely descriptive and theoretical, with limited empirical evidence on learning outcomes, especially when compared to the international research (Liang, 2023; Shi et al., 2023). Therefore, conducting a bibliometric analysis to identify the current state of research and gaps between Chinese and international studies is both timely and essential for providing research insights.

As mentioned above, the main purpose of this study is therefore to systematically analyze number of publications, key authors, institutional and national/regional collaborations, funding sources, and keywords in Chinese and international literature on K-12 engineering design using visualization tools like CiteSpace and VOSviewer, and further to compare their research trends to offer valuable insights for advancing K-12 engineering design research.

## 2. Methodology

Bibliometric analysis is a common method for statistical evaluation of literature, relying on quantitative data analysis (Li, 2023). In this study, CiteSpace and VOSviewer, two widely used tools for visualizing research on specific topics, were employed to analyze Chinese and international literature related to K-12 engineering design from a quantitative perspective.

### 2.1 Data Sources

The bibliometric data were sourced from the China National Knowledge Infrastructure (CNKI) and Web of Science (WoS) Core Collection database. CNKI is recognized as one of the most comprehensive databases for Chinese academic publications, while WoS Core Collection is renowned for its extensive global coverage across various disciplines. For the Chinese literature, an advanced search in CNKI was conducted using "工程设计" ("engineering design") as the primary keyword. The search focused on publications classified under "Educational Theory and Management," "Preschool Education," "Primary Education," and "Secondary Education" within the Social Science II category. The time range was set from January 1, 2010, to April 1, 2024. To ensure the quality and relevance of the results, only research articles and theses were selected, while news articles, conference announcements, and similar materials were excluded. After filtering, 86 publications were included in the analysis. For the WoS Core Collection database, the search formula was defined as ((TS= (engineering design) OR TS= (engineering design process)) AND DT=(Article)). The search period was also set from January 1, 2010, to April 1, 2024. After screening, 170 academic works were identified as relevant to the study.

### 2.2 Data Analysis Methods

First, the bibliometric data exported from the CNKI and WoS Core Collection databases were subjected to descriptive statistical analysis using Excel 2024. This analysis included number of publications, sources and citation of publications, and funding sources for both Chinese and

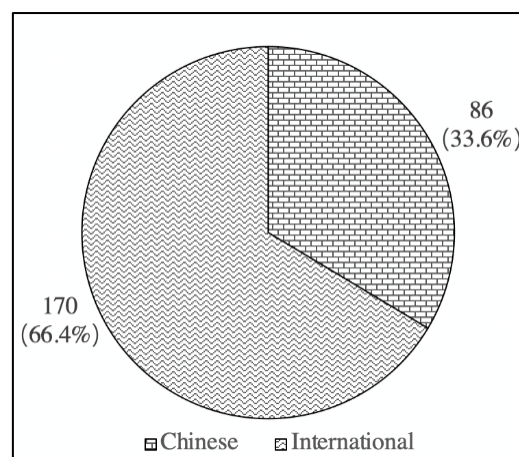
international literature. Next, the RIS-format files of Chinese bibliometric data were imported into CiteSpace for transformation and further analysis. VOSviewer (version 1.6.20) was used to examine co-authorship, institutional and national/regional collaboration networks, journal co-citation, and keyword co-occurrence. CiteSpace (6.3.1) was used to perform visual analyses of keyword, including clustering and burst detection, based on Chinese and international literature data. The parameters were configured with a time range of 2010–2024 and a time slicing interval of one year.

### 3. Results

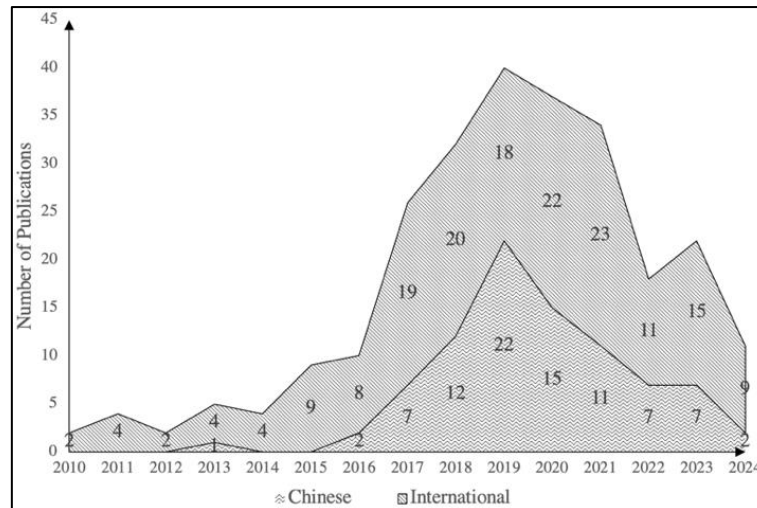
Utilizing the visualization capabilities of CiteSpace and VOSviewer, this study compared the progress and research trends in Chinese and international K-12 engineering design research from various perspectives, including number of publications, research collaboration networks among authors, institutions, and countries/regions, source and citation of publications, funding sources, and keyword.

#### 3.1 Number of Publications

A total of 256 publications on K-12 engineering design were identified from the CNKI and WoS Core Collection databases. Statistical analysis in Excel revealed significant disparities between Chinese and international literature in terms of number of publications. As presented in Figure 1, international publications (170 articles, 66.4%) were approximately twice the number of Chinese ones (86 articles, 33.6%). Figure 2 revealed that annual Chinese publications before 2017 were limited but exhibited rapid growth thereafter, peaking in 2019 with 22 studies. However, a sharp decline followed. After 2014, the quantity of international publications has started to increase, entering a phase of rapid growth starting in 2017. Between 2017 and 2021, annual publication levels remained consistently above 18 articles. Nevertheless, a notable decline occurred in 2022, with only 11 articles published. Overall, during the 2010–2024 period, both Chinese and international publications showed initial low output in the early stages, rapid growth after 2016 and 2014, respectively, and notable fluctuations around 2020 and 2022. Preliminary data from the first quarter of 2024 suggested that international publications in this field are expected to rebound and grow further.



**Figure 1: Proportion of Chinese and International Literature**



**Figure 2: Number of Publications by Year (2010-2024)**

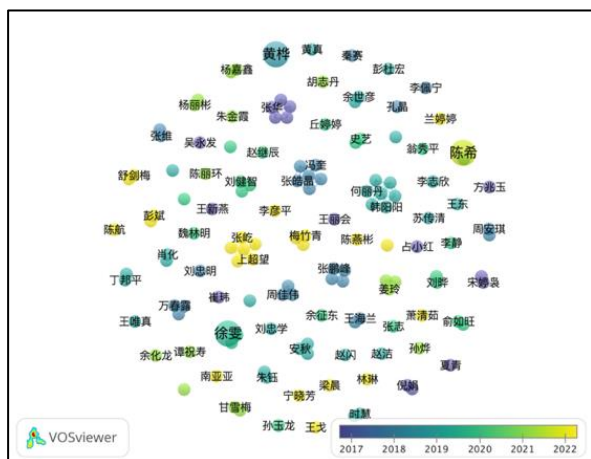
### 3.2 Collaboration Among Authors, Institutions, and Countries/Regions

The analysis of authors, using VOSviewer, revealed that the dataset includes 139 and 391 authors in Chinese and international academic works, respectively. For the former, only three have published more than one paper (see Table 1), specifically Chen Xi and Xu Wen from Shanghai High School and Nanjing Normal University Affiliated Middle School, and Huang Hua from Shanghai Normal University. Collaborations among authors were limited, as indicated by the lack of network connections between authors in the Figure 3. For authors of international publications, six have published more than four papers, with the top five all affiliated with Purdue University in the United States (see Table 1). Notably, Benda M. Capobianco has published 10 papers, forming a research team centered around him (see Figure 4). Within Purdue University, the research team was tightly connected; however, there was minimal collaborations between different research teams.

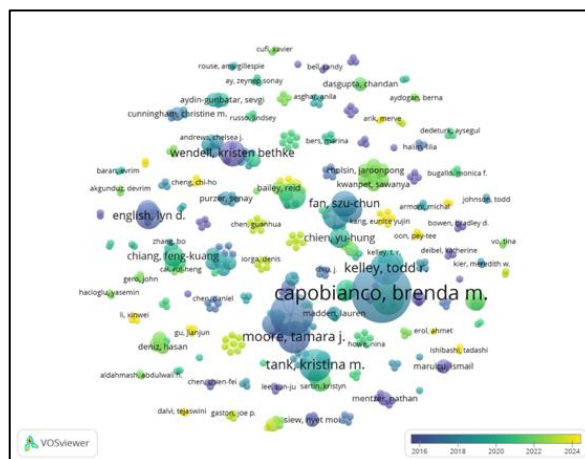
**Table 1: Top 3 Chinese and Top 6 International Authors by Publication Volume**

No	Chinese authors	Institution	Publication Volume	International authors	Country	Institution	Publication Volume
1	Chen Xi	Shanghai High School	2	Brenda M. Capobianco	U. S	Purdue University	10
2	Huang Hua	Shanghai Normal University	2	Siddika S. Guzey	U. S	Purdue University	7
3	Xu Wen	High School Affiliated to Nanjing Normal University	2	Tamara J. Moore	U. S	Purdue University	5
4				Jeffrey Radloff	U. S	Purdue University	5
5				Todd R. Kelley	U. S	Purdue University	5
6				Kristina M. Tank	U. S	Iowa State University	5



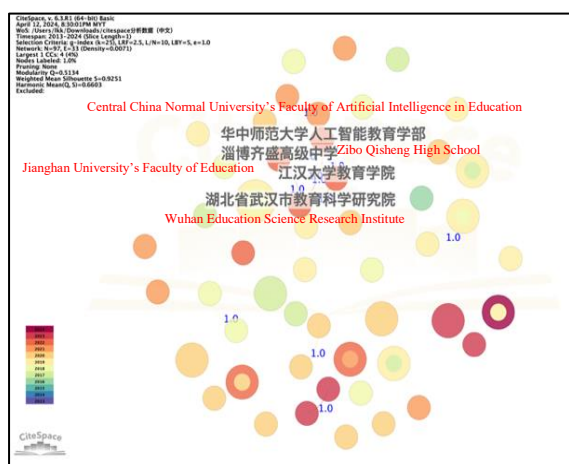


**Figure 3: Co-occurrence Map of Chinese Literature Authors**

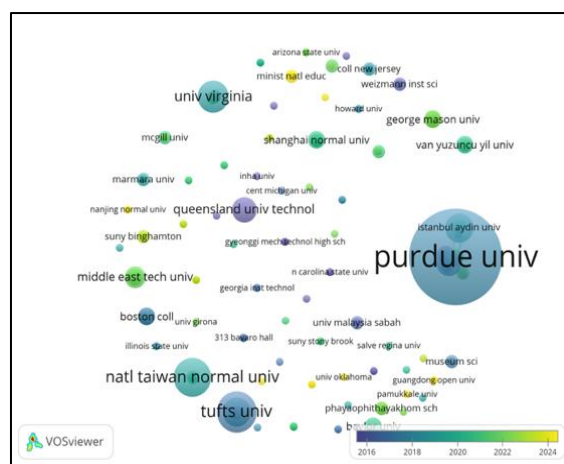


**Figure 4: Co-occurrence Map of International Literature Authors**

An analysis of Chinese institutions using CiteSpace and Excel showed that 97 institutions have contributed to K-12 engineering design research over the past 15 years, with 11 institutions publishing more than one paper. The College of Teacher Education at East China Normal University led with the highest number of publications (3 papers). It is noteworthy that the most prolific Chinese authors were not from the institutions with the most publications. The network density of institutional collaborations was low, indicating fragmented cooperation (see Figure 5). Geographically, institutional collaboration tends to be strong within specific regions, such as the collaboration between Central China Normal University's Faculty of Artificial Intelligence in Education, Jiangnan University's Faculty of Education, and the Wuhan Education Science Research Institute. In regards of international literature, VOSviewer's analysis showed that these 170 articles were collectively authored by scholars from 182 affiliations around the world. Among these, eight institutions have published more than five papers, with Purdue University leading with 33 papers. As shown in Figure 6, the inter-institutional collaboration was relatively sparse, reflecting the earlier findings regarding author collaboration. According to Excel analysis of international publications, 20 countries and regions have contributed to international K-12 engineering design research. As shown in Figure 7, the United States led with 108 papers, followed by Turkey (22 papers) and Taiwan, China (12 papers). Although the United States is one of the earliest countries to conduct engineering design research, its collaborations with other countries/regions was also limited (Figure 8).



**Figure 5: Institutional Collaboration Map of Chinese Literature**



**Figure 6: Institutional Collaboration Map of International Literature**

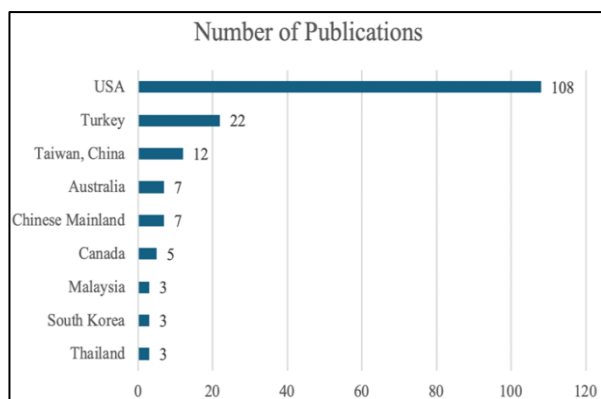


Figure 7: International Publication Volume

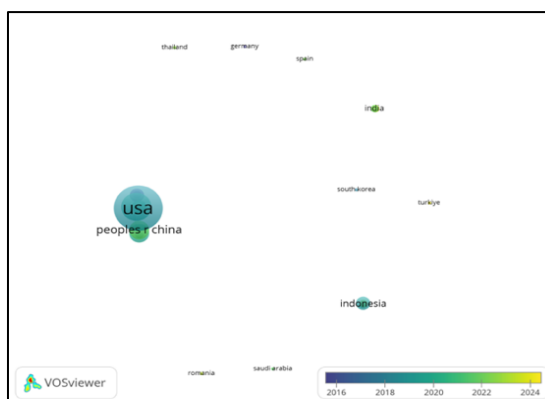


Figure 8: National/regional Collaboration Map

### 3.3 Sources and Citations of Publications

The statistical analysis of Chinese literature revealed that these publications were distributed across 62 journals and university theses. The sources publishing more than one paper/thesis toward K-12 engineering design were provided in Figure 9, with the journal Hubei Education (Science Course), China Information Technology Education, and Teaching Reference of Middle School Chemistry publishing 4 papers. Figure 10 exhibited the sources of international literature by using VOSviewer. 61 journals were identified, with 10 journals publishing more than 5 papers. The International Journal of Technology and Design Education had the highest publication count, with 19 papers.

Citation is an important indicator of the recognition and impact of research papers, reflecting trends and hot topics in the field (Ding, Zheng, & Wu, 2010). As listed in the Table 2, the top seven most-cited Chinese papers focused on using engineering design to implement STEM education in primary and secondary schools and developing STEM curricula and teaching models. Others explored case studies of engineering design-based teaching and U.S. interpretations of engineering design. The top 10 most-cited English-language papers included five that focus on the impact of engineering design on elementary school students, three that examine its effects on middle school students, and others that address teacher professional development in engineering design (Table 3). It's clear that the integration of engineering design with core education subjects has received both attentions. Chinese literature focused more on defining K-12 engineering design, exploring its implementation paths, and developing related curriculum resources, while international research placed greater emphasis on empirical studies examining the effects of engineering design, particularly its impact on elementary school students' learning outcomes.

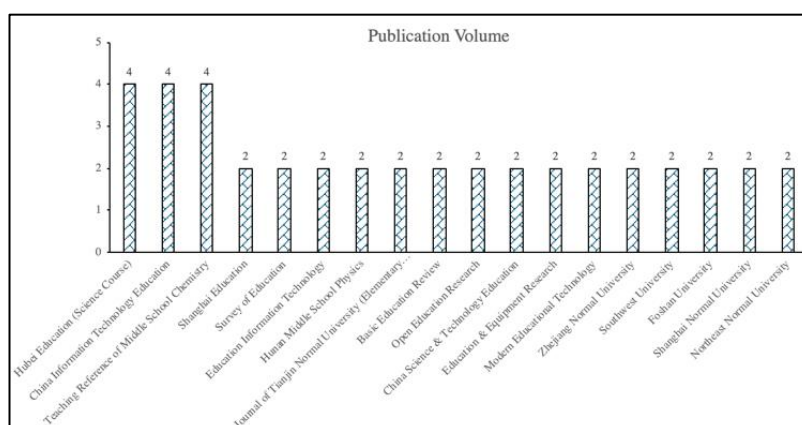
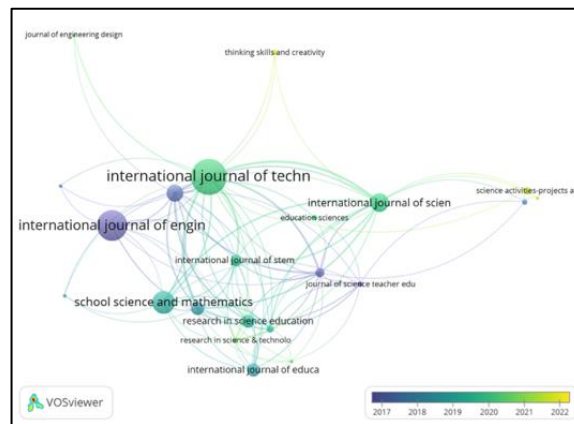


Figure 9: Sources with More Than Two Chinese Publications



**Figure 10: Co-citation Map of International Literature Sources**

**Table 2: Top 10 Most-cited Chinese Literature**

No	Title	Sources	Citations
1	Research on a Creativity-oriented STEM Teaching Model	Open Education Research	73
2	Construction and Reflection of Preschool STEM Teaching Activities from the Perspective of Project Teaching	Shaanxi Normal University	69
3	The Teaching Mode of STEM-integrated Engineering Design and its Application Oriented to the Cultivation of Computational Thinking	Modern Distance Education Research	50
4	New Engineering Education: A STEM Perspective	Open Education Research	48
5	The Practical Routes of Deeply Integrating STEM Education into the Science Course Teaching	Modern Education Technology	47
6	Engineering Design: An Effective Approach to STEM Curriculum Integration	Shanghai Research on Education	45
7	Integrating Engineering Practices into Elementary Science Education: The Connotation, Goal and Approach	Journal of Schooling Studies	40
8	The Design and Practice of Engineering Design-based STEM Curriculum in High School	Modern Education Technology	34
9	Research on “K-12 Engineering Education” Centering on Engineering Design: Origin, Connotation and Implementation Strategy: Implications of the Report “Science and Engineering for grade 6-12: Investigation and Design at the Center”	Journal of Distance Education	32
10	Development of Primary School Science Cases Based on STEM Education: A Case Study of 'Small Water Tank'	Nanjing Normal University	24

**Table 3: Top 10 Most-cited International Literature**

No	Title	Sources	Citations
1	Engineering Design-Based Science, Science Content Performance, and Science Attitudes in Elementary School	Journal of Engineering Education	96
2	STEM learning through engineering design: fourth-grade students' investigations in aerospace	International Journal of STEM Education	85
3	How an integrative STEM curriculum can benefit students in engineering design practices	International Journal of Technology and Design Education	75
4	Engineering Design and Conceptual Change in Science: Addressing thermal energy and heat transfer in eighth grade	International Journal of STEM Education	73
5	A High-Quality Professional Development for Teachers of Grades 3-6 for Implementing Engineering into Classrooms	School Science and Mathematics	63
6	Reflective Decision-Making in Elementary Students' Engineering Design	Journal of Engineering Education	60
7	Sixth-Grade Students' Views of the Nature of Engineering and Images of Engineers	Journal of Science Education and Technology	59

8	Middle-school teachers' understanding and teaching of the engineering design process: a look at subject matter and pedagogical content knowledge	International Journal of Technology and Design Education	53
9	The Impact of Design-Based STEM Integration Curricula on Student Achievement in Engineering, Science, and Mathematics	Journal of Science Education and Technology	52
10	Engineering Design Thinking: High School Students' Performance and Knowledge	Journal of Engineering Education	52

### 3.4 Funding Sources

The funding of a project reflects the level of importance attached to the topic. An analysis of the funding sources for these 256 papers showed that 26 out of 86 Chinese papers (30.2%) received funding. Those supported by the Humanities and Social Sciences Research Fund of Ministry of Education were the most numerous, totaling 4 publications (Table 4). Within provincial-level research funding, a relatively higher number of papers have been published with support from Fujian and Guangdong provinces. Table 4 showed that, among the 170 English-language papers, 97 (57.1%) were funded. The U.S National Science Foundation (NSF) provided the most support, funding 56 papers, followed by 30 papers supported by NSF's STEM Education Board. The Australia and Taiwan have also shown interest in engineering design in K-12 education. Compared to other countries/reigns, research funding for K-12 engineering design in the Chinese mainland still lags behind.

**Table 4: Top 6 Funding Scores Published in Chinese and International Publications**

No	Funding Sources for Chinese Publications	Times	Funding Sources for International Publications	Times
1	Humanities and Social Sciences Research Fund of Ministry of Education	4	National Science Foundation (NSF)	56
2	Fujian Province Education Science 13th Five-Year Plan Project	3	NSF Directorate for STEM Education	30
3	Guangzhou Education Science Project	3	Australian Research Council	4
4	Guangdong Province Science and Technology Development Special Fund	2	Ministry of Science and Technology Taiwan	4
5	Guangdong Province Higher Education Guangdong Province Teaching Reform Project for Undergraduate Universities	2	National Research Foundation of Korea	3
6	National Natural Science Foundation of China	2	Directorate for Education and Human Resources	2

### 3.5 Keyword Analysis

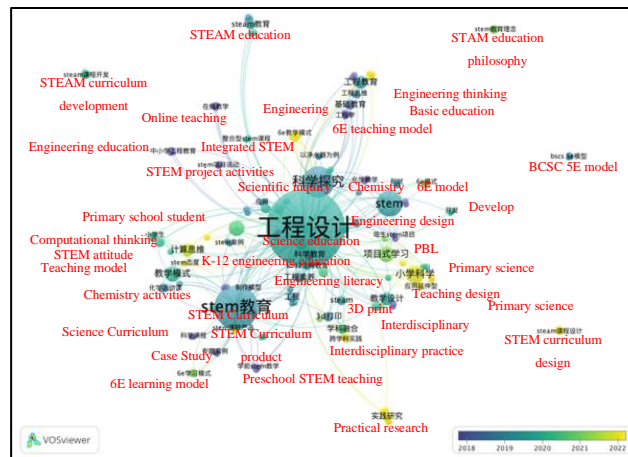
Keyword analysis plays a crucial role in academic research by identifying core themes and trends in a field. This study further conducted keywords co-occurrence, clustering, and burst analysis to identify core themes in K-12 engineering design literature, visualizing development trends and providing insights for future research.

#### (i) Keywords Co-occurrence Analysis

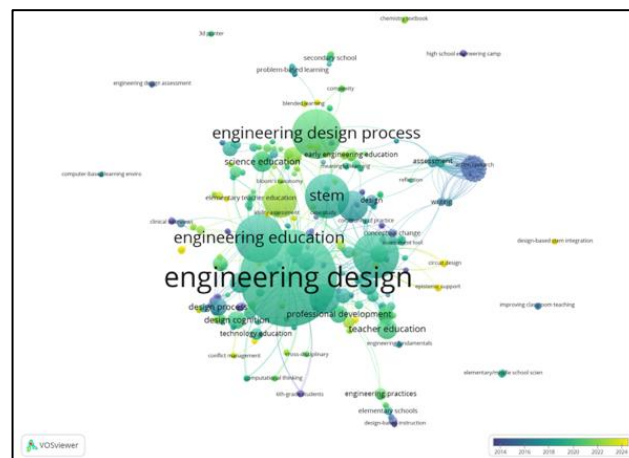
VOSviewer software is widely used due to its unique advantages in keyword analysis (Song & Chi, 2016). Therefore, this study employed VOSviewer to conduct a co-occurrence analysis of keywords in Chinese and international literature related to K-12 engineering design. The co-occurrence map of keywords in the Chinese literature revealed 159 keywords (see Figure 11). The larger the node, the higher the frequency of the keyword in the literature. In addition to "engineering design," frequently appearing keywords include STEM education, scientific inquiry, and STEM curriculum, indicating significant correlations between engineering design, STEM education, and scientific inquiry in the Chinese literature. In addition, the color of the



nodes reflects the time of keyword occurrence. It can be observed that in recent years, the primary research focus has been on topics such as computational thinking, the 6E teaching model, and practical research. The co-occurrence analysis of keywords in the international literature identified 607 keywords (see Figure 12), with 46 keywords having a frequency greater than 5. Apart from the "engineering design" node, other frequently appearing keywords include science education, thinking, inquiry, primary and secondary school students, and professional development. Recent attention has increasingly been directed toward teacher education, the influence of different teaching environments, and students' proficiency at various educational levels. The analysis suggested that the international works cover a broader range of research topics and involves a more diverse range of research subjects.



**Figure 11: Co-occurrence Diagram of Keywords in Chinese**



**Figure 12: Co-occurrence Diagram of Keywords in International Literature**

### (ii) Keyword Clustering Analysis

In CiteSpace, keyword clustering analysis was conducted using the Latent Semantic Indexing (LSI) algorithm. The clustering analysis of Chinese literature revealed five clusters, as shown in Figure 13. The clustering modularity (Q) value was 0.5134 (greater than 0.4), indicating that the clustering network was valid. The average silhouette value (S) was 0.9251 (greater than 0.5), demonstrating high homogeneity within the clusters and strong connectivity among the keywords. Similarly, the keyword clustering map for international literature (Figure 14) showed a Q value of 0.5171 (greater than 0.4) and an S value of 0.8094, confirming that the clustering network for international literature keywords was both reasonable and effective.

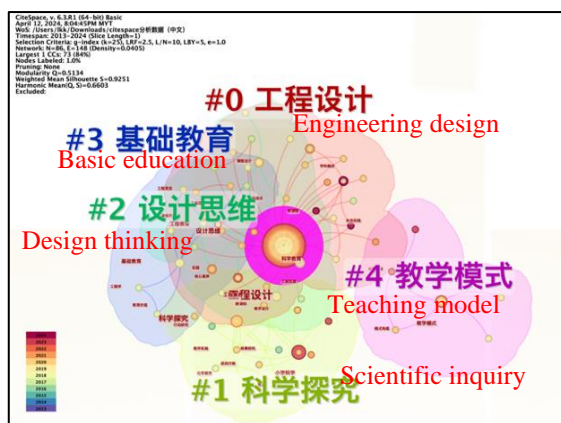


Figure 13: Keyword Clustering Network of Chinese

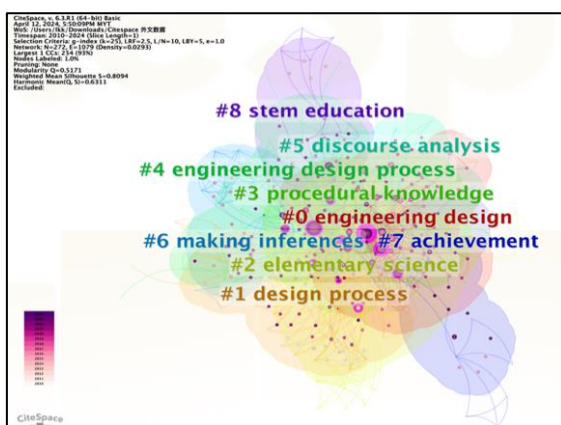


Figure 14: Keyword Clustering Network of International Literatures

The main keywords in each cluster of the Chinese literature (Table 5) revealed the following research themes: Cluster #0 focused on engineering design and physics concepts based on cognitive apprenticeship, particularly in the context of mechanics; Cluster #1 related to the connection between engineering design, scientific inquiry, and elementary science education; Cluster #2 and Cluster #4 focused on the construction of engineering design curricula and teaching models aimed at developing design thinking and engineering thinking, especially in robotics education; Cluster #3 focused on the objectives and content of engineering education within K-12 education. In terms of international papers (Table 6), Cluster #0 and #2 emphasized the requirements of engineering design teaching for teachers' subject knowledge and teaching methods, particularly for elementary teachers. Cluster #1 investigated the characteristics and processes of engineering design, while Cluster #3 explored the development goals of engineering design for students, focusing on procedural knowledge, subject concepts, and computational thinking. Cluster #4 focused on the influence of STEM education, based on the engineering design process, on the learning performance of gifted elementary students and its integration with inquiry-based curricula.

Table 5: Keyword Clustering Analysis of Top 5 Chinese Literatures

Cluster Name	Number of Nodes	S	Year	Key Keywords
#0 Engineering design	26	1	2019	Engineering Design; STEM Education; Mechanics Concepts; High School Physics Teaching; Cognitive Apprenticeship
#1 Scientific inquiry	14	0.826	2019	Scientific Inquiry; Engineering Design; Elementary Science; Instructional Design; Teaching Experiment

#2 Design thinking	11	0.853	2018	Design Thinking; Engineering Design; STEM Education; Curriculum Design; Curriculum Model
#3 Basic education	7	0.911	2018	Basic Education; Engineering Thinking; Engineering Concepts; Engineering Education; Engineering Design
#4 Teaching model	6	0.968	2020	Teaching Model; Computational Thinking; Engineering Design; Model Construction; Robotics Education

**Table 6: Keyword Clustering Analysis of Top 5 International Literatures**

Cluster Name	Number of Nodes	S	Year	Key Keywords
#0 Engineering design	53	0.697	2017	Engineering design; Science education; Teacher tensions; Elementary teacher; Teacher sense-making.
#1 Design process	37	0.844	2017	Design process; Design research; Engineering pedagogy; Inductive learning; Engineering education
#2 Elementary science	32	0.908	2012	Elementary science; Engineering education; Design-based teaching; science content knowledge; Teacher decisions
#3 Procedural Knowledge	21	0.769	2018	Procedural knowledge; Engineering design; Conceptual knowledge; computational thinking; social cognitive career theory
#4 Engineering design process	29	0.805	2018	Engineering design process; Elementary school; STEM education; Gifted students; Inquiry-based Curriculum

A timeline analysis of the clusters in CiteSpace revealed the time span and interconnections between clusters. The timeline map for the Chinese literature (Figure 15) showed that Clusters #0 (engineering design) and #1 (scientific inquiry) had the longest time span, indicating that the integration of scientific inquiry with engineering design to enhance students' conceptual understanding had been a long-standing focus in K-12 engineering design research in China. Clusters #2 (design thinking) and #3 (basic education) had time spans that end before 2020, suggesting a decline in research on the development of engineering design-based curricula in recent years. Research on Cluster #4 (teaching models) has increased since 2019, although interest has also decreased in recent years. The timeline map for the international literature (Figure 16) showed that Clusters #0 and #1 had longer time spans, indicating sustained interest in engineering education in K-12 settings, the connection between engineering education and science education, the engineering design process, and teacher preparation in engineering design education. Clusters #2 and #3, with recent time spans ending in the last few years, suggested a decline in research focusing on conceptual understanding of both teachers and students. Clusters #4, #6, and #7, with time spans starting around 2013, indicated ongoing attention to the integration of engineering design with inquiry-based curricula, student learning strategies, and the factors influencing the effectiveness of engineering design education.

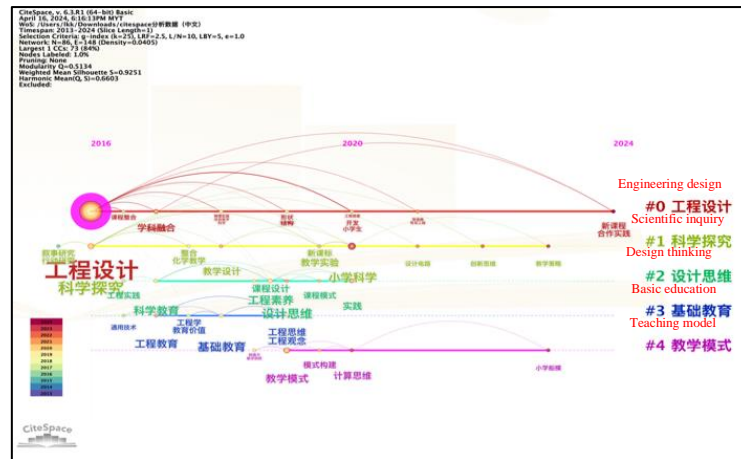


Figure 15: Key Clustering Timeline of Chinese

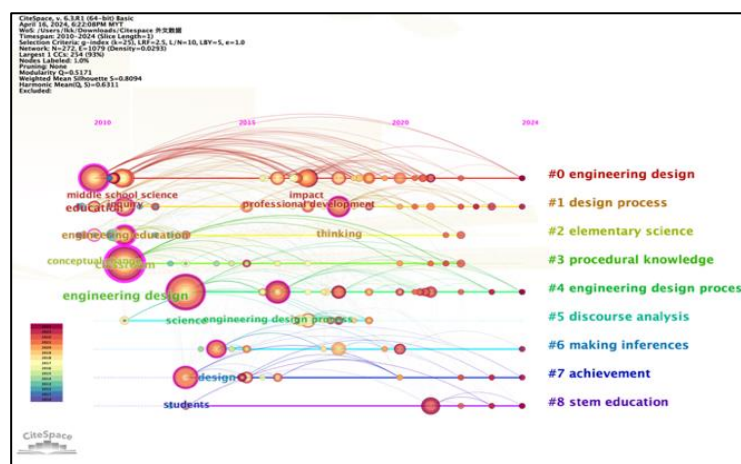


Figure 16: Key Clustering Timeline of International Literatures

### (iii) Keyword Burst Analysis

A rapid increase in the frequency of certain keywords over a short period often reflects emerging research topics that attract the field's attention, providing insights into the future direction (Li & Chen, 2017). Using keyword burst analysis in CiteSpace, the top citation bursts keywords in the Chinese and international publications were listed in Figure 17 and Figure 18, respectively. The research on K-12 engineering design in China over the past 15 years could be broadly classified into three directions: a) constructing the concept of engineering design in basic education; b) constructing STEM curricula and teaching models based on the integration of science and engineering; and c) developing and teaching STEM curricula based on the integration of technology and engineering. From theoretical research to curriculum resource development and practical effects, China's research on engineering design has garnered significant academic attention and made notable progress. In the Chinese literature, the prominence of these keywords was most evident between 2018 and 2022, suggesting that this area of research has gained increased attention in recent years. Figure 18 illustrated that significant attention was given to engineering design process models around 2011. Subsequently, the focus shifted towards the professional development of educators to implement engineering design, the goal orientation of K-12 engineering design, and the factors affecting the effectiveness of its implementation. In recent years, research has increasingly concentrated on examining the learning outcomes of engineering design and its integration with science and other subjects. Comparing the burst keywords between Chinese and international literature, it is clear that Chinese literature placed more emphasis on theoretical research on the concept and approaches of engineering design, as well as curriculum development, while

international literature was more focused on empirical studies on how engineering design enhances student learning and the factors influencing its effectiveness.



Figure 17: Top 6 Keywords with the Strongest Citation Bursts in Chinese Literature

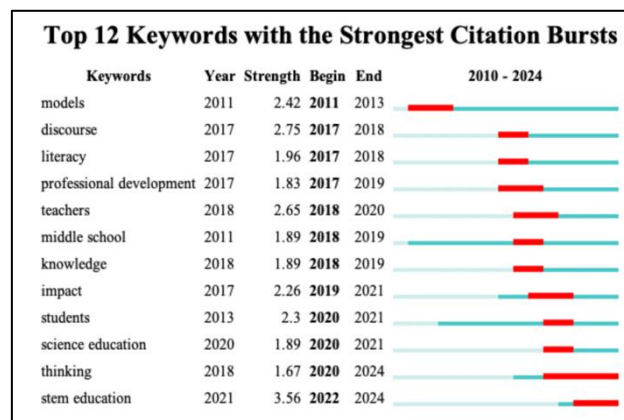


Figure 18: Top 12 Keywords with the Strongest Citation Bursts in International Literature

#### 4. Discussion and Implications

The present study employed a bibliometric analysis to systematically examine Chinese and international literature on K-12 engineering design, using data from the CNKI and WoS Core Collection databases for the period 2010–2024. The findings revealed that there were significant differences between Chinese and international literature on K-12 engineering design. While Chinese research has reached half the volume of international publications, it predominantly focused on theoretical aspects—such as the conceptualization of engineering design, its methodologies, and curriculum and teaching model development—whereas international research was more oriented toward empirical studies. These studies explored the impact of engineering design on student learning outcomes, the factors that influence its effectiveness, and teacher professional development. This disparity suggests that engineering design research in China is still in its early stages, with a primary emphasis on theoretical and descriptive investigations. It is evident that the empirical study has clearly been a significant contributor to the research community. In the study of Lin et al. (2019), the proportion of empirical studies exceeded 90% among articles published in the selected science education journals from 1998 to 2017. Therefore, to advance engineering design research in Chinese K-12 education, it is crucial to pay more attention on empirical research. Investigating how engineering design affects student learning outcomes—such as problem-solving abilities, creativity, technological application skills, teamwork, and interdisciplinary thinking—will provide critical insights into its practical effectiveness (Arik & Topçu, 2020; NRC, 2009). Additionally, exploring factors that influence the success of engineering design teaching, such as teacher roles, curriculum design, and learning environments, will offer valuable guidance



for improving educational practices (National Academies of Sciences, Engineering, and Medicine, 2020).

The rapid increase in publications on K-12 engineering design since 2017, notably following the introduction of engineering design in the Next Generation Science Standards (Ali & Tse, 2023), has contributed to the surge of global interest in the field. Despite a decline in research productivity during the COVID-19 pandemic (2020–2022), the number of international publications showed a recovery in 2023, reflecting the sustained attention given to engineering design by international scholars. However, although the overall number of Chinese publications was close to half of the international publications, its growth trend has weakened after the pandemic, which could be attributed to limited funding for research projects. The analysis of funding patterns revealed that while nearly 60% of international publications received project support, only about 30% of Chinese publications were funded, and the proportion of national-level funding in China remains relatively low. This funding gap may partially explain the slower recovery of research in China and underscore the need for increased financial support and policy development to promote the advancement of engineering design research. Providing more national-level funding and special grants can stimulate high-quality, evidence-based studies and help bridge the gap between theoretical exploration and empirical investigation (Tylor et al., 2023; Ou et al., 2024). These efforts would significantly contribute to the development of a robust research ecosystem for engineering design in K-12 education. In addition, the analysis of collaboration patterns indicated that collaborations among Chinese researchers were relatively sparse. While only a few Chinese authors have published multiple papers on this topic, there is one well-established research network in the United States, centered around institutions like Purdue University, where several scholars have published extensively on K-12 engineering design. This difference highlighted the importance of fostering collaborative research teams in China. Previous studies have highlighted that establishing a diverse and collaborative research network is key to advancing engineering design by fostering interdisciplinary exchange (Luo et al., 2023; Smith, 2024). Thus, measures such as establishing multidisciplinary research platforms, and providing targeted funding for collaborative projects can be implemented to enhance interdisciplinary exchange and innovation in engineering design (Shi & Li, 2019; NIES, 2017; Chang et al., 2017). Promoting international collaborations is also crucial for researchers worldwide, as it could facilitate the sharing of resources, expertise, and established research paradigms (Lecorchick et al., 2020; Lederman et al., 2021). For Chinese scholars, engaging in joint international research projects and academic exchanges can improve the quality and scope of domestic research, aligning it with global best practices. In regard to the international communities, the findings revealed that, apart from collaborations within institutions in the United States, domestic and international cooperation in other countries/regions has been limited. Thus, establishing diverse and interdisciplinary research networks, especially with scholars from non-English-speaking countries (Lin et al., 2019), is also worth emphasizing.

## 5. Limitations

While this study provided valuable insights into the research trends and comparative analysis of engineering design in K-12 education, some limitations of this study could also provide insights for future research. First, the reliance on bibliometric tools such as CiteSpace and VOSviewer may have introduced biases due to variations in database coverage, indexing practices, and keyword selection, potentially omitting relevant studies. Specifically, this study utilized CNKI and WoS as the primary databases for Chinese and international publications. Researchers interested in engineering design could also build upon the methodology of this

study, expanding the database selection to conduct further in-depth research and provide new insights into the field from a broader perspective. Another limitation of this study is related to its quantitative focus, emphasizing aspects such as publication volumes and collaborations, which may overlook qualitative aspects of the research. Future research could pay more attention to qualitative analyses, focusing on key research areas in engineering design to explore deeper insights and address context-specific issues.

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