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The frontiers and hotspots of computational thinking cultivation research for primary and secondary school students

-- Literature analysis based on CNKI database in the past 13 years (2010-2023)

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Abstract: Computational thinking is the key to cultivating students' core literacy in the information age, and it is also an important entry point to promote the reform of information technology curriculum. In order to understand the development trend of computational thinking cultivation of primary school students in China in the past 13 years, this paper took CNKI as the data source to statistically analyze the published literature in China. From the perspectives of the number of literatures, publishing institutions, authors, etc., this paper reviews the research on the cultivation of computational thinking among primary school students in China in the past 13 years. This paper puts forward the problems and thoughts existing in the research on the cultivation of computational thinking of primary school students from the aspects of research theme, research content and research methods.

Keywords: Computational thinking; Primary school student; Cultivate; Citespace.

1. Introduction

The definition of computational thinking has always been a controversial issue in the academic world, from the time it nurtures ideas, sprouts and grows to the time it is officially recognized by the society. And it first appeared in the world in 1980 when Seymour Papert, a professor at MIT, proposed the interdisciplinary value of computational thinking.and learning with computational thinking[1]In 1996, he emphasized again in his research. But it was Professor Jeannette M. Wing of Carnegie Long University (CMU) who really brought computational thinking into the public's view. In 2006, she proposed that "computational thinking is a series of thinking activities covering the breadth of computer science, such as problem solving, system design, human behavior understanding, etc., using the basic concepts of computer science". In 2011, it put forward that computational thinking is thinking activity and analytical thinking, and comprehensively used mathematical thinking, engineering thinking and scientific thinking. It shows that computational thinking is a process from isolated thinking activities to comprehensive thinking. In China, in 2017, the Ministry of Education clearly listed computational thinking as one of the core qualities of information technology discipline in high schools[2]In 2022, the Ministry of Education incorporated information technology (IT) into the national curriculum for compulsory education, and computational thinking became one of the core literacies of the IT curriculum. In 2022, the new standard said that computational thinking refers to the individual use of computer science ideas and methods, in the problem solving process involving abstraction, decomposition, modeling, algorithm design and other thinking activities.[3]The acquisition of computational thinking has become a foundation that, like reading, writing, and arithmetic, should be a must for all. The development of computational thinking has become more and more important as it has been widely recognized by the international computing and education communities. At the same time, the cultivation of computational thinking is a long-term and systematic process, therefore, it is necessary to carry out research on the cultivation of computational thinking from the elementary school stage.

This paper makes statistics on the articles published in CNKI in this field from 2010 to 2023, and uses Citespace to analyze the selected papers. Citespace obtains the co-occurrence relationship between keywords by constructing a keyword co-occurrence matrix. When the word frequency is high, it indicates that the higher the importance of the keyword in this field, the higher the research value. Citespace can be used to obtain the statistical data and visual expression of the research field, from which the internal relationship between the knowledge structure of the field and the domain knowledge can also be found. At present, Citespace based analysis methods have been widely used in review writing. Citespace based analysis methods can be used for field hotspot analysis, research evolution path analysis, research group analysis, etc., which plays a key role in tracking the development of academic fields[4]The analysis of the previous work allows us to find out the status of the development of computational thinking in primary school students and provides a reference for further research in this field. By analyzing the work done by previous authors, it is possible to find out the state of development of computational thinking development in primary school students and provide reference ideas for further research in this field.

2. Research design

2.1. Data sources and processing

2.1.1. Sub-section Headings

CNKI is selected as the basic data source for this study. CNKI has collected more than 8000 journals with extensive contents, which is the largest real-time updated Chinese literature database. In the information age, computational

thinking has become a topic of increasing concern. As a way of thinking, it is of great significance for human development. I selected the literature of the past 13 years for analysis, so I set the search period as January 2010 to November. 2023, set the search method as advanced search, set the search theme as "primary school students' computational thinking training", and set the resource type as journals, doctoral and master's theses. A total of 492 documents were retrieved, and irrelevant documents in Chinese conferences, foreign conferences and other fields were deleted, 472 articles were selected as the main data source of this study.

2.1.2. Research methods and tools

The research methods used in this study mainly include: (1)bibliometric method, which gives an objective evaluation of the status quo of primary and secondary school students' computational thinking research from the perspective of data-driven by analyzing the publication time, issuing agencies, and the number of articles published by the authors of the CNKI database research literature on computational thinking training; (2) Visual analysis research method, using CiteSpace software developed by Dr. Chen Chaomei, School of Information Science and Technology, Drexel University, the United States, carries out visual analysis on 470 articles. On the one hand, through the keyword clustering atlas and keyword co occurrence time zone atlas, we explore the hot spots and training paths of computing thinking training for primary school students in China. On the other hand, it analyzes the literature authors, institutions and their cooperation network atlas of computational thinking training of primary school students in China to understand their spatial distribution characteristics and cooperation. (3)Content analysis method, highly cited literature is an important knowledge base for the cultivation of primary school students' computational thinking in the big data environment. Combining the clustering results, this study analyzes highly cited literature and summarizes the hot spots and frontiers of primary school students' computational thinking cultivation.

3. the current state of research on the development of computational thinking in primary and secondary schools

3.1. Statistical analysis of the volume of communications

The number of papers issued indicates the degree of attention paid to a certain research field, and the number of consecutive papers issued year by year can reflect the change trend of this research field. CNKI search results show that China's research on education big data enabling education evaluation can be roughly divided into two periods (see Figure 1):

1. Initial period (1980-2016). On the whole, when information technology began to flourish in the early period, only a few scholars paid attention to the term computational thinking, and only a few scholars began to explore the related aspects. Computational thinking is an indispensable way of thinking in the information society, just like the ability of listening, speaking, reading and writing. The more information technology advances, computational thinking and social progress is linked, but the research on computational thinking in this period shows a weak concern, the number of articles is relatively small. 2010- 2016, both at home and abroad, there are scholars began to pay attention to the cultivation of computational thinking, the following table is the important events related to the cultivation of computational thinking: the following table is the important events related to the cultivation of computational thinking.

Table 1. A compendium of important events in computational thinking that

	Countries/institutions	Time	corresponding policies and
Abroad	European industry and the scientific community	2007	Convened a conference on "Thinking Science: Europe's Next Policy Challenge" to illustrate the importance of computational thinking
	Computer Science Teachers Association (CSTA) 213	2011	The introduction of "K-12 Computer Course Standard" marks that computational thinking has officially entered the course standard.
		2016	The course content of "CSTA K-12 Computer Science Framework" places "computational thinking" at the core of five aspects.
	UK	2013	"The New Curriculum Project has made computational thinking an important element of its new information technology curriculum, suggesting that a high-quality computing curriculum education will develop students' computational thinking and creativity to enable them to understand and change the world.
	Australia	2015	The "New Curriculum Program" includes computational thinking as an important element of its new information technology curriculum.
	The Joint Research Center of the European Commission	2016	Launch of the Study on Developing Computational Thinking in Compulsory Education.
	New Media Consortium and American Association for Information Technology in Higher Education Learning Project	2017	The NMC Horizon Report: 2017 Basic Education Edition points
Domestic	C9 University Alliance	2010	The Joint Statement of C9 Basic Computer Teaching Development Strategy emphasizes that "cultivating students' computing thinking ability is an important, long-term and complex core task of computer teaching in colleges and universities".
	Ministry of Education	2012	The Ministry of Education has promoted reform of the university computer curriculum with a focus on the development of computational thinking.
	Steering Committee for Teaching Computer Courses in Higher Educational Institutions, Ministry of Education	2013	Publication of the Declaration on the Reform of Computer Teaching, which aims to improve the level of computer applications by fostering awareness and methods of computational thinking among students.

As you can see, there is a growing interest in computational thinking, both abroad and at home, and its importance cannot be overstated.

2. Rapid growth period (2017-2023). During this period,

more and more researchers devote themselves to the study of the field of computational thinking cultivation, and the cultivation of computational thinking of primary school students in China has been greatly accumulated in these years, both in theory and practice. The education sector began to realize that the cultivation of computational thinking is a long-term and systematic process, and elementary school is the key period for the cultivation of logical thinking ability, so the attention to the cultivation of computational thinking in elementary school is getting higher and higher, but in view of China's educational reform, has been to the macro-structural adjustment is the main focus, has always been the basic education information technology courses do not pay attention to the computer science education and research is relatively weak, the cultivation of talents is generally not high quality; most of the researchers devote themselves to the field of research on the cultivation of computational thinking in elementary school students in these years, both theoretical and practical aspects, have accumulated a lot. The quality is generally not high; most teachers are difficult to establish a link between the unfamiliar computational thinking and educational scenarios, in the teaching process, there are certain obstacles to the implementation of the lack of equipment, teachers and students for the use of equipment, lack of knowledge, etc.; computational thinking training in the basic education stage of the system is not in scale. In terms of the research object, China pays more attention to the cultivation of computational thinking in higher education, and the combination with basic education is still insufficient; the teaching of computational thinking cultivation has a single measure in the field. In terms of research content, the research is more limited and single. The research focuses more on the exploration of the model and the development and application of specific software for computational thinking, and the teaching software is only the carrier of teaching practice, which is not equivalent to the practice itself. The interdisciplinary development of computational thinking needs to be "separated from the science of computation"; to explore new developments in cognition and pedagogy. And in our country the cultivation of computational thinking, the main position is still information technology disciplines and other aspects of these issues, China's path to the cultivation of computational thinking of primary school students is still in a more difficult point, but also the majority of educators and researchers should strive to aspects. The cultivation of computational thinking of primary and secondary school students has been a hot topic in recent years, mainly focusing on the solution of the above problems.

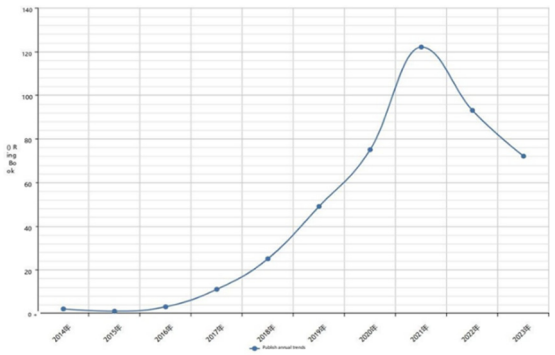

Figure 1. Annual number of publications

3.2. Statistical analysis of highly cited literature

After analyzing the authors of the papers, the following results were obtained: Xie Zhongxin, Yu Xiaohua, Wang Meiling, Cai Ronghua, Cao Yanglu and other authors have published three or more papers, put forward a lot of concepts as well as theoretical and practical significance of research on the cultivation of primary school students' computational thinking in the information age, and greatly promoted and contributed to the development of the field, and this kind of spirit is worthy of learning from the younger generation, and academic results are also quite fruitful and worthy of our learning. This spirit is worth learning from our younger generation, and the academic achievements are also quite impressive and worthy of our study. In addition, there are many scholars who have been working on this area of research, so we can learn from the rich academic results and try to open up a new situation and a new chapter in the development of computational thinking of primary school students. (As shown in Figure 2).

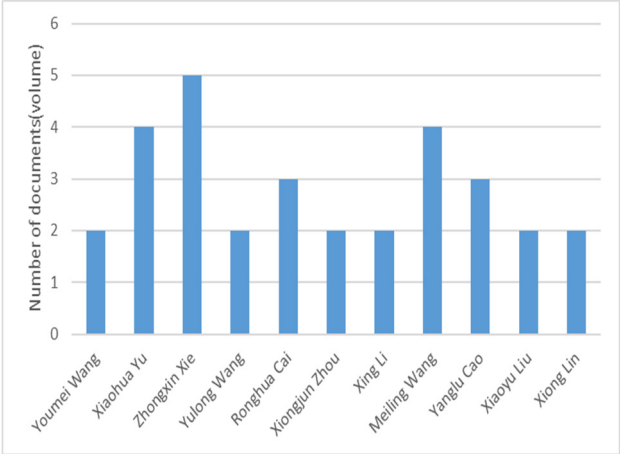

Figure 2. Map of authors of publications

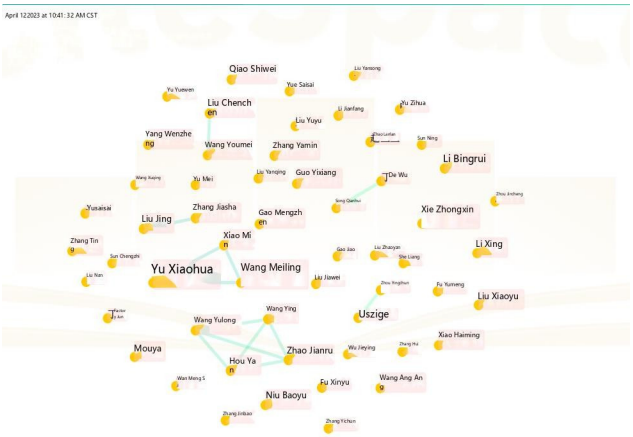

Figure 3. Author Cooperation Network

In CiteSpace the cooperation among different authors can be understood by the author cooperation network map (see Figure 3). Specifically, there are 106 nodes and 18 connections in the map. The overall density of the network is only 0.0032. The nodes are almost distributed in isolated spots, with only sporadic cooperation links. It can be seen that most of the research authors of computational thinking of primary and secondary school students in China are in an isolated research state, lacking cohesion and centripetal force,

and the core research team has not yet formed. But at the same time, there are individual "stars and moons" phenomenon. The core authors Yu Xiaohua and Wang Meiling have continuous cooperation with several authors in the field, and they are the core authors in the field of computational thinking training in China.

3.3. Statistical analysis of publications issued by research organizations Analyzing

the issuing institutions of the 470 papers obtained from China Knowledge Network, we found that the distribution of issuing institutions is mostly in teacher training colleges and universities, and the largest number of articles is from East China Normal University, which has published 29 articles in this field, followed by Shaanxi Normal University, Shanghai Normal University, Northwest Normal University, and Northeast Normal University, whose number of articles is gradually decreasing and all of them are more than 10, and the others basically come from major teacher training colleges, there are still a certain number of researchers who pay attention to the cultivation of computational thinking. (As shown in Fig. 4)

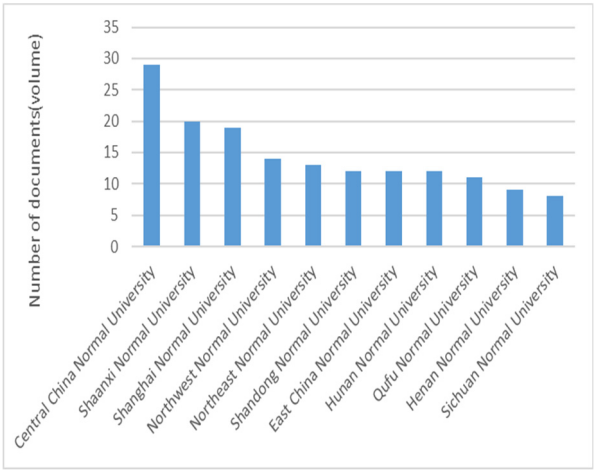

Figure 4. Diagram of the issuing organization

In CiteSpace, the cooperation between different institutions can be understood from the institutional cooperation network map (see Figure 5). Specifically, there are 152 nodes and 26 connections in the map, and the overall density of the network is only 0.023. Central China Normal University has cooperation with other schools, while other schools are isolated, with little cooperation.

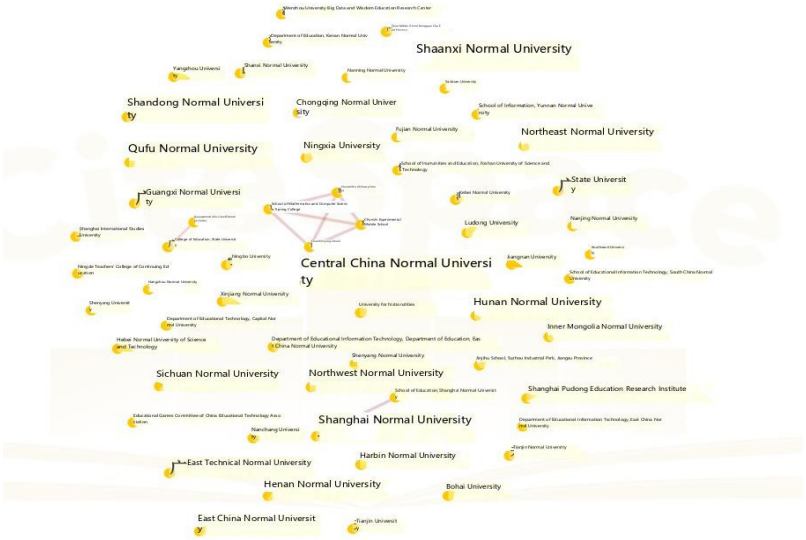

Figure 5. Map of the collaborative network of computational thinking development organizations that

3.4. research hotspots for the development of computational thinking in primary and secondary schools

3.4.1. Keyword co-occurrence mapping

Key words are a high generalization of the whole literature, and the frequency of key words can be used as a proof to judge whether a research direction is a research hotspot in the field to some extent. Centrality is another important indicator to measure research hotspots. Centrality reflects the pivotal role of keywords in different clusters. Referring to these two indicators, we can judge the current and future research hotspots. From the consistency and difference of the two indicators, we can find the coupling relationship between different research directions of computational thinking training. Using CiteSpace software, according to the default parameters, select Keyword to analyze 474 articles, form a keyword co-occurrence network, and analyze 232 nodes, 420 edges, with a density of 0.0157.

Table 2 shows the top 10 keywords in terms of frequency according to CiteSpace software. The key word with the highest frequency was computational thinking, which appeared 375 times; The second is teaching design, which has appeared for

50 times; The third teaching mode is 43 times. Because the cultivation of computational thinking needs to be reflected by a certain carrier, the high frequency of teaching design and teaching mode is correct. Information technology and primary and secondary schools ranked fourth and fifth respectively, reflecting that the research direction related to these two keywords is the core research content - because the country is paying more and more attention to the cultivation of computational thinking, and the cultivation of computational thinking is a long-term process, there is no doubt that the foundation is laid from primary school, which is also beneficial to the long-term development of students. In addition, programming education Teaching strategies, core literacy, App inventor and artificial intelligence also appear more frequently in the table.

It can be inferred that the research directions represented

by these keywords have also attracted the attention of scholars, which are hot research directions in recent years. And these words have great relevance to the cultivation of computational thinking. (as shown in Table 2)

Table 2. Top 10 keywords in terms of frequency

number	Frequency	Centrality	Keywords	number	Frequency	Centrality	Keywords
1	375	1.38	Computational thinking	6	20	0.11	programming education
2	50	0.17	instructional design	7	20	0.07	teaching strategies
3	43	0.13	Teaching and Learning Models	8	14	0.02	core literacy
4	35	0.19	information technology	9	13	0.03	App inventor
5	22	0.13	Primary and secondary schools	10	54	0.08	Artificial Intelligence

In the ranking of centrality, the keyword computational thinking has the highest centrality value of 1.38, which indicates that computational thinking is the first priority when exploring the hotspots for the cultivation of computational thinking in primary school students, followed by considering how to design how to cultivate computational thinking with the help of instructional design and teaching mode. (As shown in Table 3)

Table 3. Top 10 keywords in terms of centrality

Number	Centrality	Frequency	Keywords	Number	Centrality	Frequency	Keywords
1	1.38	375	Computational thinking	6	0.11	20	programming education
2	0.19	35	information technology	7	0.08	13	Artificial Intelligence
3	0.17	50	instructional design	8	0.07	20	teaching strategies
4	0.13	43	Teaching and Learning Models	9	0.07	12	Thought Development
5	0.13	22	Primary and secondary schools	10	0.07	4	Practice

By comparing Table 2 and Table 3, we can find that computing thinking, teaching design, teaching mode, information technology, primary and secondary schools, programming education, artificial intelligence, and teaching strategies have all appeared, which indicates that in the relevant research on the cultivation mode of primary school students' computing thinking, the combination of information technology, teaching design, and teaching mode research to cultivate computing thinking is the focus of primary school students' cultivation. Key words such as core literacy and App inventor with high frequency and low centrality are widely concerned, but their connectivity is poor, and further research is needed; However, AI and practice with high centrality and low frequency have not yet become hot spots, which are potential research directions and need further research.

3.4.2. Keyword Clustering View

In order to further explore the relationship between each topic and reveal the distribution of topic clustering, this study used LLR (Log like hood Ratio) algorithm for clustering, and finally 35 topics were counted, with a Q value of 0.6053, greater than 0.3, and a significant clustering structure. S value=0.9299. If it is greater than 0.7, the clustering results have high reliability. (As shown in Figure 6)

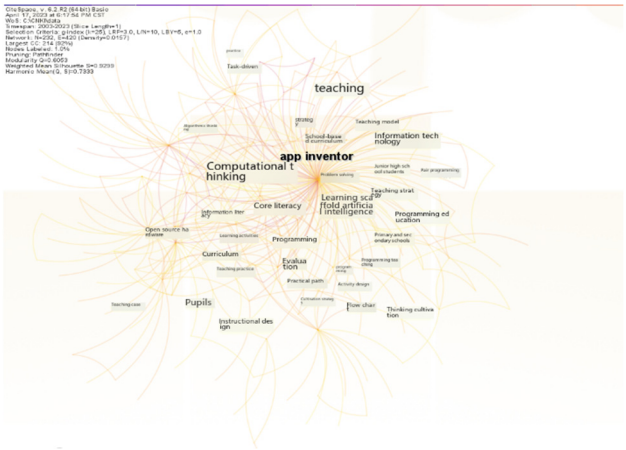

Figure 6. Keyword clustering view

4. Research trends in the development of computational thinking in primary and secondary schools

4.1. keyword emergence analysis

set up γ= 0.7, the default Minimum Duration is 2, and 13 salient words are obtained, which are ranked according to the order of occurrence year, namely: information technology (2013-2017), primary and secondary schools (2013-2017), information literacy (2014-2019), information literacy (2014-2019), strategy (2015-2019), App inventor (2017-2018), core literacy (2017-2018), primary education (2017-2019) Problem solving (2018~2019), training strategy (2018~2019), curriculum development (2018~2020), training (2018~2019),

project learning (2020~2021), mathematics (2020~2021). This indicates the research focus at each time stage. (as shown in Figure 7)

Figure 7. Keyword emergence map

4.2. Timeline view analysis

CiteSpace's timeline view analysis shows the trend of research topics over time, including the rise, development and decline of hot spots, by visualizing time series literature data. This method identifies co cited groups and distinguishes hot spots and sub domains in different periods by color or shape, reflecting the change of their influence. Key literature nodes indicate important progress or changes in research, while clustering dynamically reveals trends, cycles and lasting themes. This interactive analysis tool not only helps researchers to deeply explore the historical context and grasp the current pattern, but also helps predict the future direction, providing strong support for review preparation, research project establishment and discipline forward- looking analysis.

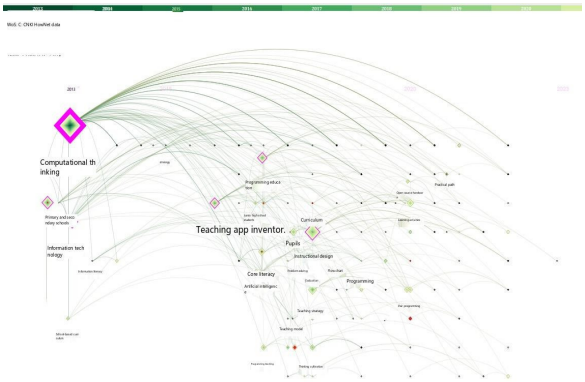

Figure 8. Time line view analysis

4.3. Studying development trends

Table 4. Research trends in computational thinking, as indicated by literature analysis and data analysis, are shown in the following table

development trends	Concrete embodiment
Popularization and early education	With the deepening understanding of the value of computational thinking, its education is gradually sinking to a lower age, including kindergartens and primary schools, emphasizing the cultivation of children's logical reasoning, problem solving and creative thinking ability from an early age.
Interdisciplinary integration	Computational thinking is no longer limited to the field of computer science, but as a basic way of thinking, it has been applied in mathematics, physics, biology, social sciences and other disciplines, promoting the interdisciplinary and innovative ability.
Practice and Situated Teaching	In educational practice, we pay more attention to situational methods such as project-based learning and case analysis, so that students can master computational thinking skills and enhance their application ability in the process of solving real-world problems.
Evaluation and evaluation system construction	Evaluation tools and evaluation systems for computational thinking are gradually being established and improved, which measure students' progress in algorithmic thinking, system design and data analysis in a scientific and quantitative way and provide feedback for the quality of education
Innovation of Technology and educational tools	With the development of technologies such as industrial intelligence and big data, more innovative educational tools and platforms (such as intelligent learning systems and virtual reality environments) will be developed to teach and evaluate computational thinking in a more efficient and personalized way.
Lifelong learning and career development	Computational thinking is regarded as one of the core competitiveness in the 21st century, and its education and training will extend to the fields of adult education and career development, helping workers adapt to the rapidly changing working environment and promoting the sustained growth of their careers.
Ethics and social responsibility	With the increasing influence of computing technology on society, computational thinking education has begun to emphasize the cultivation of ethics, privacy protection and social responsibility, and guide students to consider its social influence when using technology to solve practical problems.
International cooperation and standard setting	Computational thinking education, international organizations and governments are cooperating to formulate a unified teaching standard and certification system to promote the internationalization of computational thinking education.

5. Summary and analysis of research contents

Through CNKI data analysis, this study studies the research status, research hotspots and research trends of computational thinking training in primary and secondary schools, providing theoretical support for researchers who study computational thinking training. Through analysis, we know that the research on the cultivation of computational thinking of primary and secondary school students has made significant progress in China, but we still need to strengthen the work in education policy support, teacher training, evaluation system construction and other aspects. Future research should focus on the depth and breadth of empirical research, explore more effective teaching models, and promote the balanced and high-quality development of computational thinking in basic education.

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