A Comparative Study on Programming Education——Based on China and America

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Abstract. In the past decade, the academia of education and computer science has regarded programming as a core competence of K-12 students. China's K-12 programming education market was launched in 2013. By 2017, the entire K-12 programming education market ushered in a period of the explosion, many of China's original K-12 programming education platforms emerged. Still, its development speed lags behind many countries led by the United States. The lack of literature on comparing K-12 programming education between China and the United States can be distinguished as a research gap in this field. It is necessary to conduct a comparative study because it can help promote a thorough understanding of their development status. The research paper mainly adopts composite methods of quantitative bibliometrics and qualitative interview to fill in this gap together with market research. The results of bibliometrics show the two developing paradigms of programming education, the research focus on computational thinking, and the trend topics of K-12 programming education among academia. Based on our Chinese market research, the teaching mode of K-12 programming education are online, offline, and blended learning. When it comes to course contents and their corresponding orientation, the elementary courses are formative education, the middle-level lessons are algorithm-oriented, and the hardest are the creative ones designed for computer competitions. Besides, most programming education curriculum starts from visual lessons and adds game elements. Through interviews with relevant professionals and teachers in China and the United States, we learned their views on programming platforms, evaluation criteria, computational thinking, and the development trend of K-12 programming education.

Keywords: K-12 programming education, China, America, co-words analysis, bibliometrics, commercialized, Community, Computational Thinking.

1. Introduction

In the past decade, programming ability has been regarded as a core competence of K-12 children [1,2]. Since 2013, countries worldwide have launched various projects to promote K-12 programming education. However, K-12 programming education in China did not begin to flourish until 2017, and the development speed lags behind many countries led by the United States [2]. Research on comparison between K-12 programming education in China and the United States can merely be found, which means the similarities and differences of K-12 programming education between the two countries are unclear in academia. To fill in this gap, it is necessary to understand the development status of the K-12 programming education market in China, explore the differences in K-12 programming education between China and the United States, clarify the focus and development trend, and put forward reliable development suggestions.

2. Literature Review

2.1. The Definition of Programming Education

In the 21st century, the continual development of digital technology makes a significant change in formal and informal education in many ways [3]. Computer Science (CS) brought a huge improvement in current technology and a globally connected world [4]. Education and technology integration brings great support for further learning, especially based on the computer application [3]. Most of the literature indicates the tendency of computer programming education in K-12 development, the use of learning platforms (e.g., Scratch), the innovation of the pedagogy (e.g., game-based learning), and programming curriculum involvement in schools in the western countries.

Computer programming becomes a vital tool for computer scientists and engineers for decades. However, current programming education is regarded as competency skills also outside the engineering field [2]. Programming Education is a small branch of STEM (Science, Technology, Engineering, Mathematics) education. It combines games, visual graphics programming, project-based learning, and robot design to help students learn about Computer Science (CS). Programming Education aims to help students develop their logical thinking skills, observation skills, practical skills, writing skills, creativity, and improve students' ability to analyze complicated tasks and solve problems in the process of programming.

Nevertheless, programming education is a notable tendency of future innovative education and adding it to the school curriculum is the predictable result for the new digital migration generation. There is a research gap about programming education. From our literature review readings, we discovered that most research regarding programming education is limited to just one country, such as Finland, The United States, and other developed countries. There are few articles, however, that focus on comparative research between different countries. Also, most literature shows the correspondence between programming education and games or computational thinking and computer science. For example, Lindberg's article states that programming with game elements has a clear purpose for entertainment or education. And game-embed education has its terminology, such as serious games, edutainment, gamification, game-based learning, and playful learning [4]. The game-based on programming education emphasizes that the creation of terms related to different educational approaches. Nevertheless, the literature reviews seldom discuss two different countries' perspectives about programming education and the effect on students.

2.2. K-12 Programming Education in China

In China, programming education started later than in developed countries (e.g., the U.S.), and certain teaching modes and models of programming learning just formed in the 1990s [6]. With the rapid development of Artificial Intelligence (AI), programming education in China has become a focus of attention and shows the trend of children and young age [7]. In March 2017, Artificial intelligence was the first time to be written to the State Council's government work report and officially entered the national strategic level [8]. In May 2017, the new generation of AI development issued by the State Council proposed implementing the national artificial intelligence education program and the establishment of AI-related courses in primary schools [8]. The related courses promoted programming education.

In China, programming education integrates the idea of STEM. The pivotal reason for the integration is that STEM education cultivates children's competencies of observing problems, pondering problems, solving problems, and promotes their logical thinking capacity [9]. The ultimate goal of K-12 programming education in Chins is to nurturing students' digital vision and promote students' creative thinking [9].

Nevertheless, China's K-12 programming education market analysis indicates that programming education in K-12 involvement rate is 0.96% [6]. Why programming education has such a low involvement rate? In the recent two years, from 2018 to 2020, an increasing number of companies started introducing K-12 programming education in this country because of the huge market benefits

[6]. Superficially, the K-12 programming education companies only surge in numbers in China, the programming education is still in the developing period. The education system is not as mature as enough, commercialization has bought an array of problems, such as the lack of the highly qualified teachers as well as systematic pedagogy and the rapidly soaring cost for most families. Also, most of the programming education follows developed countries' education pattern, including programming tools utility. For example, the most famous visual programming tool-Scratch is popular in many commercialized Chinese education institutions. Scratch has a relatively simple visual programming environment that encourages users to create interactive, media-rich projects, including animated stories, games, online news shows, book reports, greeting cards, music videos, science projects, tutorials, simulations, and sensor-driven arts [8].

2.3. K-12 Programming Education in the United States

The independent K-12 Computer Programming Education in the United States appeared transitory in the late 1970s and transformed rather fast into other types of computer-assisted education [2]. It is apparent that programming education has a strong connection to computer sciences which plays a vital role in current technology and the globally connected world [4]. Also, according to Yadav, Hong, and Stephenson's research, computer-assisted education becomes the main tendency that focuses on cultivating children's computational thinking.

Computational thinking is regarded as a key 21st-century competence for all students has led to a number of curriculum initiatives to embed it in K-12 classrooms. The thinking pattern involves three key constructs: Algorithms, Abstraction, and Automation, the three as of computational thinking. The idea of computational thinking under programming education allows students to develop a fundamental understanding of computing and develop competencies that move them from technology users to producers of information technology. Also, programming education in the United States is more likely to integrate game-based learning. In the game-based learning environment, young people always are parts of the games where they are better or more knowledgeable about what they are learning and how they could engage in the content.

Furthermore, it is important to truly understand how computer technology changes traditional learning and connected community. Programming Education is associated with educational software, which young people consider beneficial technology and use as a starting point for creating. The youth try to figure out what and how the programming skill could bring to their learning environment and create a connected community. Programming education provides technology-supported learning that facilitates the connected community. The program Mobile City Science is a typical empirical example [11]. Mobile City Science is a way to collect real-time dynamic data and interpret space to teach Youth how to create spatial data and visualization function by itself in the STEM curriculum. It makes crucial decisions for the community, and more wisely incorporate Youth themselves into valuable cities participants. The STEM curriculum offers outside classroom opportunities for students to integrate technology to recognize the public, community settings relevant to their daily lives.

Nevertheless, there are some limitations for programming education in the United States as well. Programming education is less likely to occur in school. Kafai's research indicates that programming education within schools remains resolutely down [11]. The College Board data shows that only 2,100 of 42,000 K-12 schools in the U.S. offer Advanced Placement computer science courses [11]. The high-level CS principles make the concept of abstraction understandable, given that a wide range of topics is covered. But the mere computational participation in the elementary technology-based course results in few students knowing basic CS principles, which is a knowledge gap due to the absence of programming course-set in early K-12 education [11]. Therefore, the programming curriculum does not fit in well with the school right now.

Moreover, Wang's study indicates that many schools' teachers have reported the difficulty of teaching programming courses [12]. From Yadav's study, we also understand that programming education is the main tendency in the education field, and CS plays an essential role in today's technology and globally connected world [4]. However, CS is not always prioritized by the school boards because there is a lack of qualified teachers and resources to train or hire teachers [4]. In this way, students are less likely to effectively learn about the programming curriculum, and schools are also unwilling to continue to offer the systematic programming syllabus.

3. Research Hypothesis

3.1. Developing Paradigms

Project-based learning and game-based learning are the two main curriculum paradigms for programming education.

3.2. Current Situation

The programming education is commercialized in China while it is well-developed in the school curriculum in other countries, especially in the United States.

3.3. Developing Trend

The development of programming education would be among the elite's children.

4. Research Method

The methods utilized in this article are R-tool-based bibliometrics, semi-structured interviews, and qualitative China market research.

4.1. Data Collection

The original text data regarding programming education in countries except China derives from the core collection of Web of Science. In contrast, the market data of China stems from the latest market research report from Zhiyan Consulting [14] and I Research [15].

When doing the retrieval, we put "K-12 programming education" OR" K-12 computing education" OR "K-12 STEM education" for the Title, and the retrieval index includes SCI-EXPANDED, SSCI, CPCI-S, CCR-EXPANDED, and IC (from Web of Science). Time Ranges from 1985 to 2021. We got 1289 valid results. After exporting and converting the original text data retrieved from Web of Science, the dataset package was put into the R-tool bibliophily for data analysis and data visualization.

4.2. Data Analysis

We abide by the recommended science mapping workflow proposed by Aria and Cuccurullo in 2017 [16], as is shown in Figure 1.

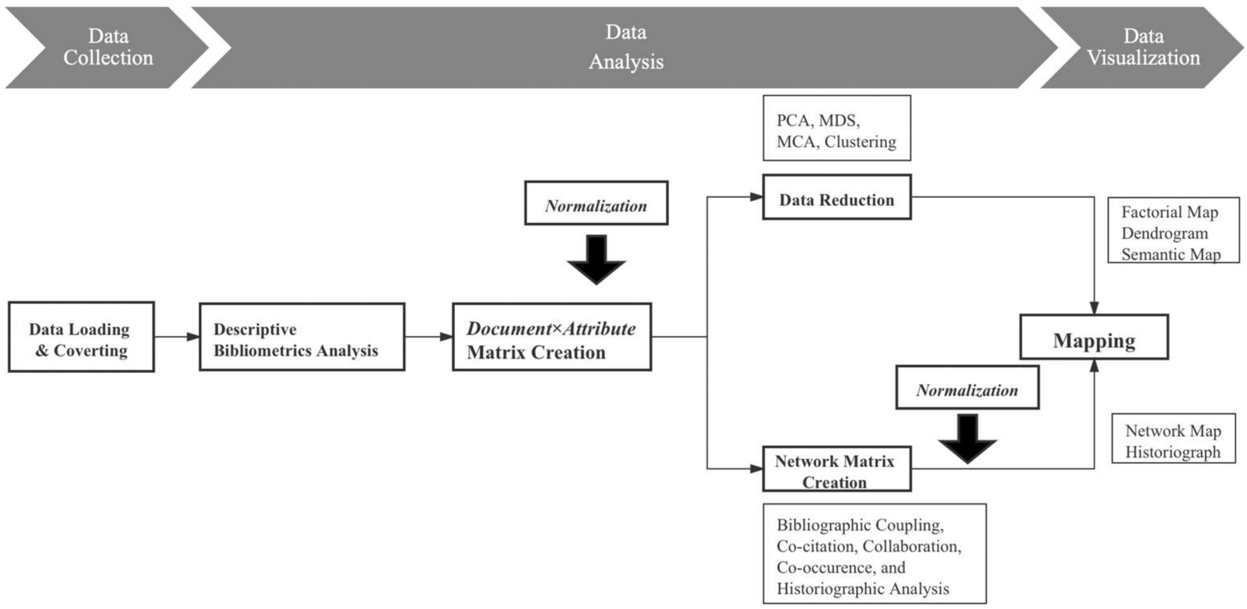

Figure 1. Bibliometrics and the recommended science mapping workflow

1) The first step: loading and converting data, which has been elaborated in the data collection part.

2) The next step: conducting the descriptive bibliometrics analysis, which describes the main information regarding the collection. In this part, we have analyzed the 20-most productive countries, as is shown in Table 2, in which the USA is leading the research because its production is far more than the second productive country.

Table 1. The twenty-most productive countries

Region	Freq
USA	1012
CHINA	298
SPAIN	109
UK	105
BRAZIL	90
INDIA	69
GERMANY	52
TURKEY	44
ITALY	42
SOUTH KOREA	41
MALAYSIA	40
AUSTRALIA	39
CANADA	35
JAPAN	33
FINLAND	30
GREECE	28
SWEDEN	28
CHILE	23
INDONESIA	22
PORTUGAL	20

3) The third step: the network creation for bibliographic coupling, which includes the co-occurrence analysis: From the Co-occurrence network Figure 2 below, which is derived from the co-word analysis based on the author's keywords, we can find that "computational thinking" is the most prevailing research topic and it is highly correlated to "computer science" courses and "programming education", also "STEM education". At the same time, "cloud computing" is another research target, which mostly contributes to "higher education" and "e-learning".

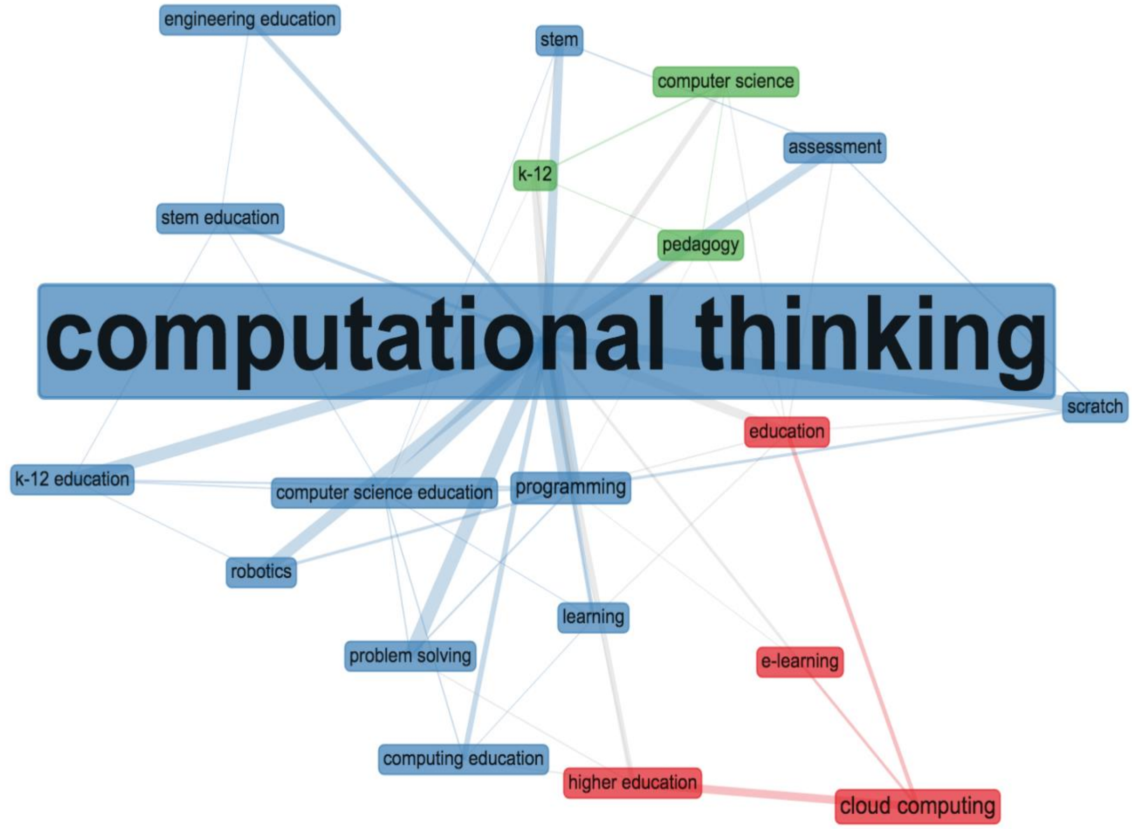

Figure 2. Co-occurrence network

4) Then it comes to the final step: network mapping. We have done the map visualization below.

a) Conceptual Structure Map: After doing the multidimensional scaling of the author's keywords, which is a method that belongs to the Factorial analysis [16], we got the conceptual map in Figure 3. From the two map scales, it can be concluded that the red one represents the traditional programming education, together with its location (e.g., elementary or middle school), course contents (e.g., robotics, scratch or plain coding), the education strategy of "blended learning" and "broadening participation" and the assessment as well as impact (self-efficacy). By contrast, the blue one stands for a new research paradigm focusing on game-based learning and creativity.

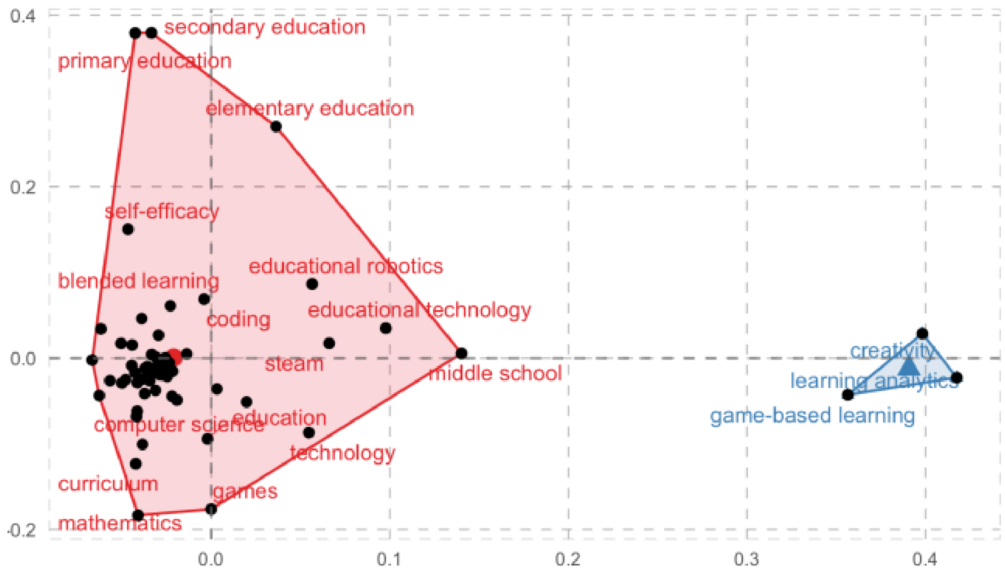

Figure 3. Conceptual structure map

b) The Trend Topics Table: Table 2 can also reflect that "cloud computing" is popular among these years, while some topics emerge these three years, such as "problem-solving" and the "elementary education", which means that other non-Chinese educators and scholars are paying more attention to elementary school programming education and the impact of these courses on students' abilities. Also, it provides a developing paradigm for programming education in China, especially for elementary learners.

Table 2. The Trend Topics Table

Item	Freq	Year
CLOUD COMPUTING	88	2016
HIGHER EDUCATION	41	2016
K-12 EDUCATION	29	2017
ASSESSMENT	28	2019
ENGINEERING EDUCATION	20	2017
E-LEARNING	15	2017
PEDAGOGY	14	2016
COMPUTING	13	2017
MODELING	13	2016
SCIENCE EDUCATION	13	2018
ABSTRACTION	12	2016
EDUCATIONAL ROBOTICS	12	2018
GAME DESIGN	12	2017
ACTIVE LEARNING	10	2016
COLLABORATIVE LEARNING	10	2018
ELEMENTARY EDUCATION	10	2020
PROBLEM-SOLVING	10	2019
PROGRAMMING EDUCATION	10	2018
VISUAL PROGRAMMING	10	2017

c) Thematic Map: from the perspective of Figure 4 thematic map, which is divided into four dimensions, cloud computing belongs to the Motor Themes [16], which means that it is well-developed and central in the research field structure, while the "computer science" is highly developed but isolated. "Computational thinking," although it is largely discussed, lacks development and is still in the basic themes, which can be shown in its low development degree together with its large radius.

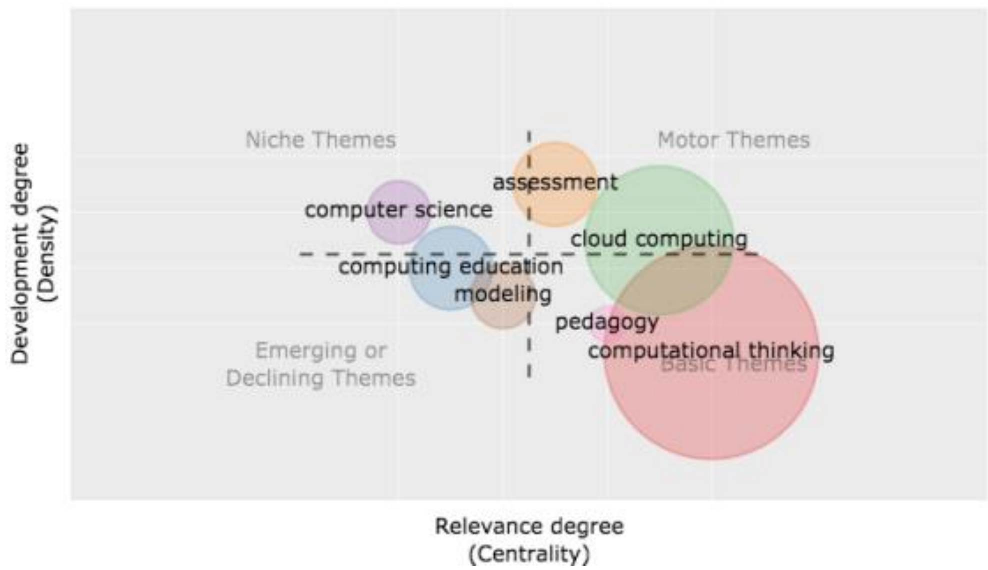

Figure 4. The Thematic Map

d) Thematic Evolution: last but not least, it is necessary to look at the general thematic evolution. It can be seen from Figure 5 that the thematic evolution can be divided into two time-slices: one is from 2003 to about 2017, and another is from three years ago up to now, which is reflected in Figure 6 and Figure 7. The thriving and declining topics are in line with the results we have drawn from above. Those whose focus was cloud computing began applying it to general learning and education, while those analyzing computing education start combining it with cloud computing. Many scholars proceed their research on computational thinking from 18 years ago till now, and those specializations on STEM education to find the importance of computational thinking these three years.

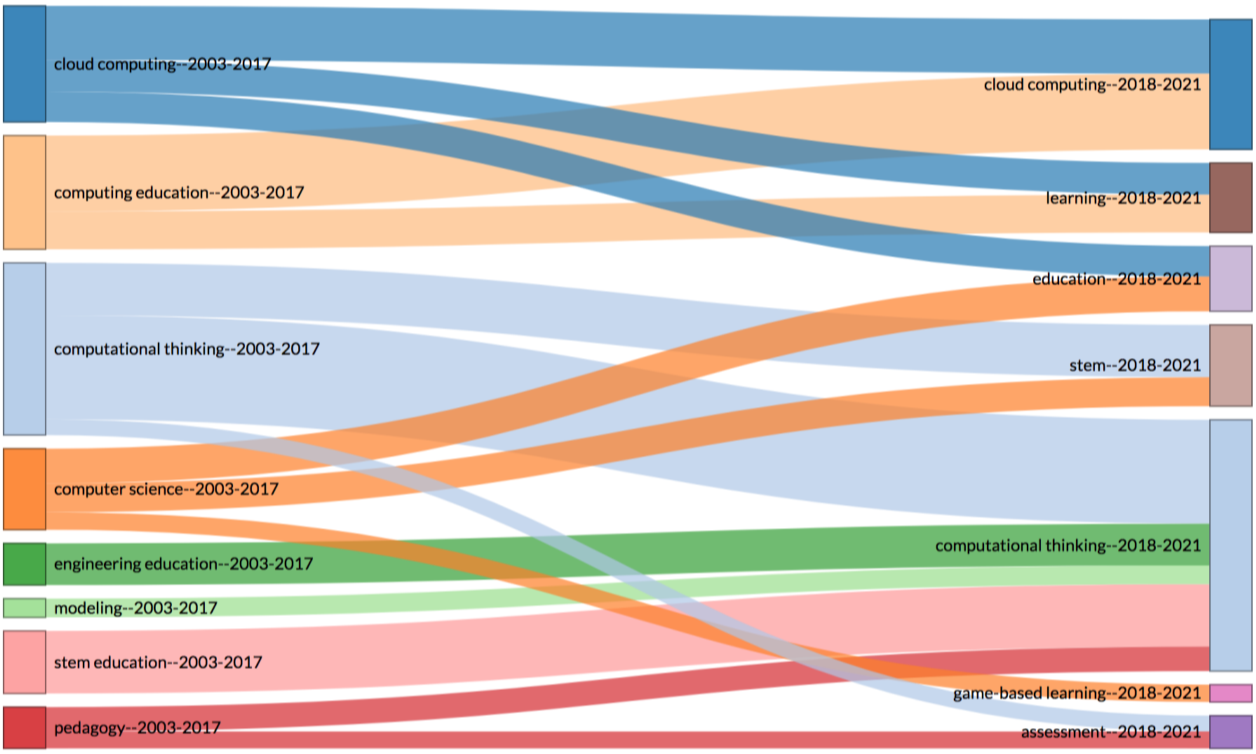

Figure 5. Thematic Evolution

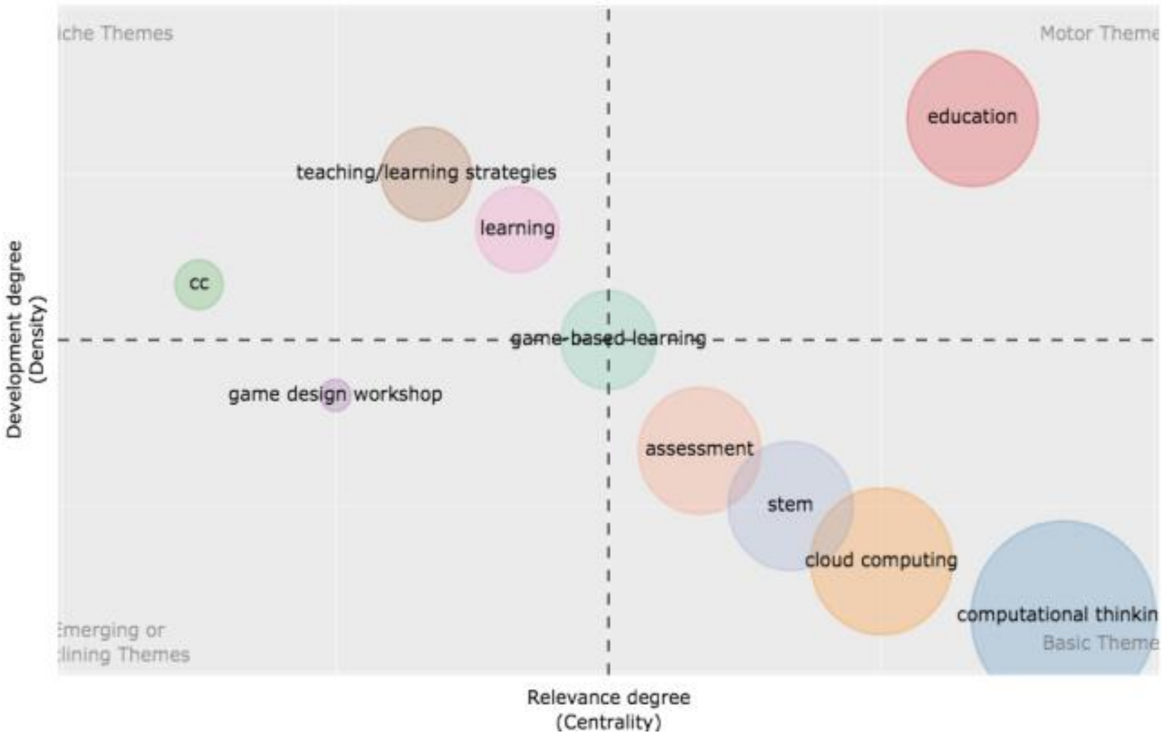

Figure 6. Thematic Evolution (2003-2017)

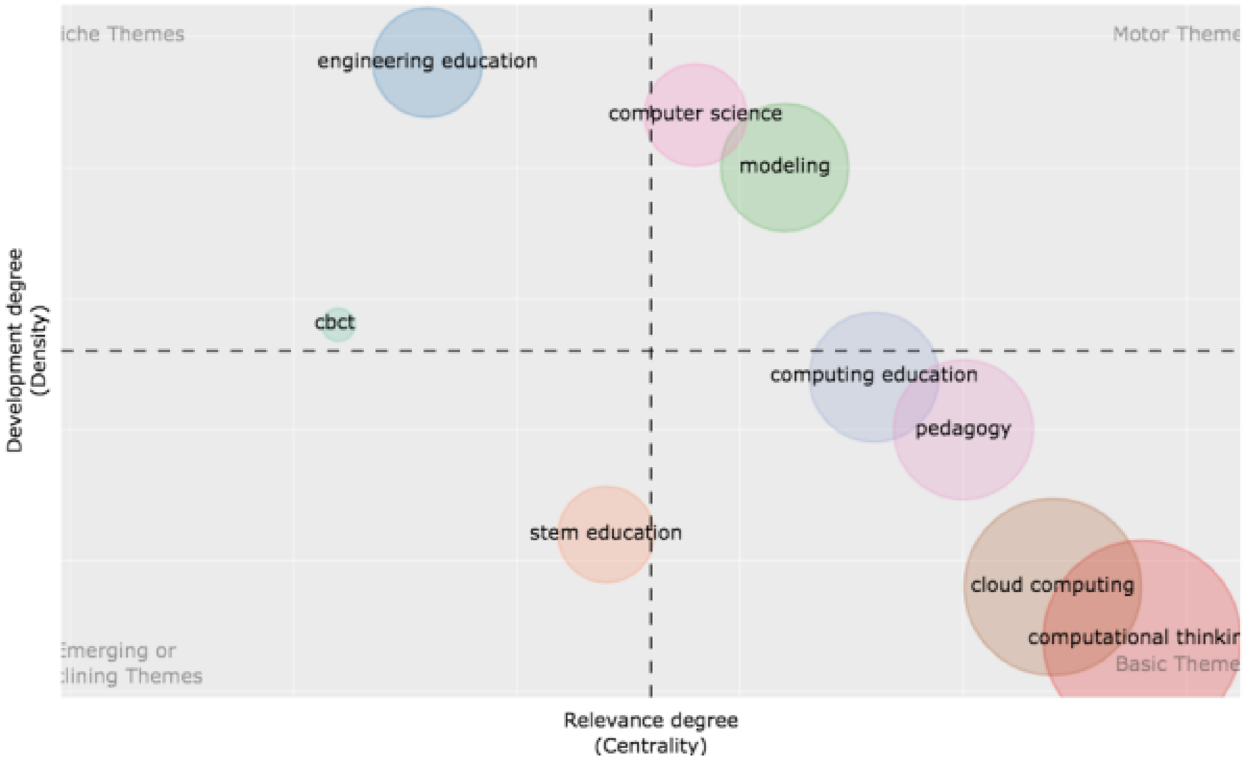

Figure 7. Thematic Evolution (2018-2021)

4.3. Thematic Analysis

1) Qualitative interview

Table 3. Interview Thematic Analysis

	Interviewee 1	Interviewee 2	Interviewee
Theme 1: Platform usage and curriculum	The scratch platform is well-designed	C++ is too difficult for K-12 education	
Theme 2: Assessment and evaluation standard	Contents are exam-oriented	Assessment methods are different	Student engagement and learning itself is what matters
Theme 3: Computational thinking	Computational thinking will be developed(algorithmic and problem-solving ability)	Computational thinking will be developed (creative ability, since it has been put as one assessing standard)	Computational thinking will be developed (the STEM education is for the problem-solving skill)
Theme 4: Developing trend	Elite community workshops designed by these well-educated parents	Developing trend: from top to bottom (according to family economic background)	Developing trend: 1. Connection Community (free for all, funded by the government, delivered in schools) 2. Education equity for women

2) Chinese Market Result: Starting from 2013, the market for K-12 programming education burst out for 5 years [17]. From the aspect of service-delivery type, all the products can be concluded as three main tracks: online, offline, and blended learning [14]. When it comes to the course contents and the corresponding degree of difficulty, the elementary courses are formative education. The middle-level lessons are algorithm-oriented, and the hardest are the creative ones. Most programming education curriculum starts from visual lessons [15].

4.4. Validity and Reliability

1) Validity: the reason we choose the composite research method is that a comparative study of two countries should be based on a thorough quantitative method and a deep-down qualitative method. The bibliometrics can quickly help us find the research paradigms of a new emerging topic [16], and the topic is K-12 programming education in this research paper. The interviews can help us explore the developing trend of K-12 PE and compare the two countries' PE current situation. The themes are listed in the order of cognitive development. The China market research is based on our literature review, from which we found that there are few research papers on K-12 programming education in China because it was introduced commercially.

2) Reliability: When doing the retrieval, we put the "K-12 programming education" for the title rather than keywords because we found that the results of the latter one are mostly irrelevant to PE education. We double checked the resulting scope by inserting "China AND K-12 programming education". Only 6/1272 results were shown, which means most data for bibliometrics analysis are based on countries except China, in which the United States is leading the research, according to Table 2. Based on the results of the bibliometrics, we narrow down our interviews and conducted semi-structured interviews with three interviewees. The three interviewees are both professionals and teachers of programming education. Their backgrounds are China, America, and hybrid. The market research we conducted and the report we utilized are the latest in China K-12 programming education.

5. Result And Discussion

5.1. Result

Three main results can be drawn from the blended analysis above. Firstly, the research paradigms for K-12 programming education are the traditional ones, including its course contents, platforms, form, assessment and impact, and the creative one embeds game. Secondly, PE is commercially developing in China, which is different from that of America. Nevertheless, the quality of PE in the two countries is similar. Thirdly, the developing trend for K-12 PE education will be the education designed for the elite community.

5.2. Discussion

Most results of our research are in line with the research hypothesis, while the current developing situation is not the same as our prediction. Both China and America lack qualified teachers and a systematic curriculum for K-12 programming education at school. The platforms and software, such as Scratch, are well-developed and can fit the needs of students from different levels.

It is noticeable that the commercialization of education in China is prevailing, which stems from the huge market income. The introduction of western courses and curriculum is popular in commercial China educational institutions, and the targets of these companies are the middle-class families. They value their children's competence in the talent market and treat the coding skill as necessary for children's skill-set. To deep down, these Chinese parents still have the exam-oriented assessing mindset, so most PE products will be evaluated through solid results (like finishing one programming picture). Therefore, the course design for the commercial institutions in China must contain a standard answer.

To develop the K-12 programming education, three suggestions were given by the three interviewees. Firstly, parents should participate in children's game-based learning, which can boost communication between parents and children and let the parents coach the children when they confront difficulties (the bugs). Secondly, the elite class can build a community like that of the Mobile City. In this reality, and CS are combined closely, and the students are both participants and the facilitators of the digital city, indulging themselves in the programming-based learning environment. Thirdly, the disadvantaged groups should be fund by the government so that they can access basic PE.

6. Conclusion

To conclude, this research paper utilized the composite methods of bibliometrics, semi-structured interview, and market research and compared the K-12 programming education in China and the United States, which filled in the research gap of this comparison between two countries.

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