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A systematic review of computational thinking: Analysing research hot spots and trends by CiteSpace

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Abstract: Computational Thinking (CT) has become popular in recent years and has been recognized as an essential skill for digital citizen. As the literature grows rapidly, a systematic review of CT and its current challenges becomes essential. Taking 395 pieces of journal articles and proceeding papers about CT research included in ISI Web of Science from 1979 to 2018 as samples, this study adopts bibliometric analysis method and visual knowledge analysis tool CiteSpace to carry out in-depth exploration of aspects such as development status, developing trend, and hot subjects of computational thinking research. The result identifies time and spatial distribution, major intellectual cooperation network, cooccurrence keywords, research clusters and landmark articles of CT.

Keywords: Computational thinking, bibliometric analysis, Knowledge mapping

1. Introduction

Computational Thinking (CT) has gained extensive attention and become popular especially after being defined by Wing in 2006. She presented that computational thinking as a way of 'solving problems, designing systems and understanding human behavior by drawing on the concepts of computer science" (Wing, 2006). Recently, many researcher do some research about CT. To better understand the current research, we proceed with a systematic review. This research adopts the literature methodology and scientific knowledge map to visualization analysis literature by using CiteSpace. Through the analysis of CT research institution, author distribution and hot topic clustering, this paper aims to understand the ramifications and research status of the computational thinking, provide references for the in-depth research, practice exploration and promotion.

2. Methodology and data collection

CiteSpace is an information visualization tool developed by Prof. Chen of Drexel University, which has now been widely used to analyze the hot topics and trends of frontier research, and the relationship between research frontiers and knowledge bases. In this research, we take the literature of computational thinking as the research object and collect data from the ISI Web of Science. The document retrieval was conducted on Feb 14, 2018, with computational thinking in the title, and the retrieval years were from 1900 to 2018. After collecting 395 papers from the WoS, we use CiteSpace to analyze existing CT literature would help provide a clear picture of intellectual cooperation network, co-occurrence keywords, timeline clusters and landmark articles in CT research.

3. Results and discussions

The period of 1979–2008 shows a slow growth with 11 related papers of journal articles and few findings in proceedings papers. The annual number of CT research in journal articles increased dramatically from 7 articles in 2009 to 52 articles in 2017. 2009 is also the beginning year of CT research in proceeding publications with 9 papers, and it grows rapidly during these years, which are more than journal articles. USA scholars started to publish CT research from the year of 1998 and published 153 papers. It is followed by China with 76 articles and Spain with 33 articles. China scholars began to do the CT research early from the year of 2009. Meanwhile, England, Brazil, Canada and Italy also made a significant contribution to make a study. University of Salamanca from Spain and Clemson University from the USA ranked first with 6 articles, followed by Carnegie Mellon University, University of Colorado and Vilnius University with 5 papers. Within those Top 10 institutions, five of them come from the USA. Two institutions from Spain made a significant contribution to CT research.

Computational thinking, education, k12, programming, scratch, computer science education, computer science, problem solving, k-12, student, design, robotics, stem, computational thinking, assessment, science education, teaching, learning, visual programming, and framework are the top 20 keywords with high co-occurrence frequency in the whole period. Keyword clustering can clarify the hot spot and development trend of a certain research field. It is apparently to find that coding, game-based learning, programming and programming languages, k-12 education, computing, secondary education, bebras challenge, k-12, and digital libraries are the hot topics in computational thinking.

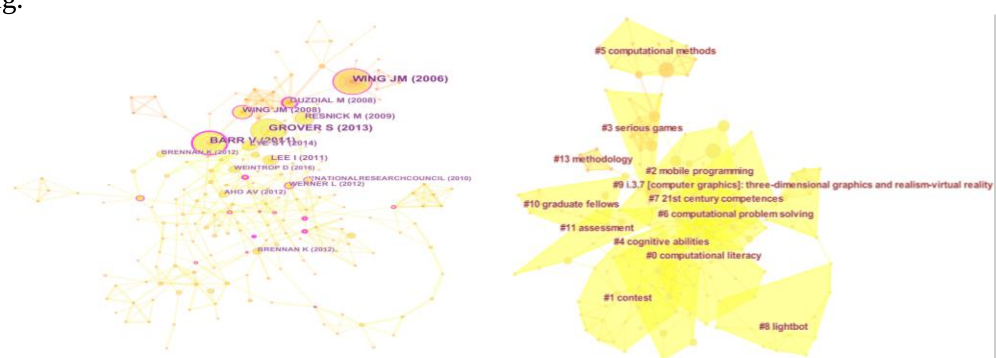

Figure 1(a). The literature co-citation network; *1(b).* Literature co-citation network keyword automatic clustering label

Seen from the bibliometrics, research literature mentioned most frequently in some field of study is usually the concentrated reflection of research hotspots in this field. The High cited literature (Top 10) of CT research are Wing(2006) (citation 61), Barr(2011) (citation 55), Grover(2013) (citation 55), Wing(2008) (citation 33), Resnick(2009) (citation 31), Guzdial(2008) (citation 25), Lye(2014) (citation 24), Lee(2011) (citation 23), Aho(2012) (citation 17), and Werner(2012) (citation 16). The literature co-citation network sees Figure 1(a). To explore research trends, we use the CiteSpace to cluster and generate the automatic clustering label. From the Figure 1(b), we can see that the cluster ranked first was ***computational literacy*** (#0). This cluster contains 26 articles studying on computational thinking; science education; modeling, mostly published around 2013. Bers and his college's (Bers, Flannery, Kazakoff, & Sullivan, 2014) study on an early childhood robotics curriculum take 13% proportion in this cluster. They described a Robotics Program paired with developmentally appropriate computer programming and robotics tools with a constructionist curriculum designed to engage kindergarten children in learning computational thinking, robotics, programming, and problem-solving. The term computational literacy is perhaps susceptible to confusion with earlier ones like information literacy or digital literacy that have assumed various meanings over the years and fall well short of what demands of computational literacy. The second largest cluster (#1) contains 26 articles studying on the ***contest***, mostly published around 2013. Dagiene and Stupuriene's study is the most cited, which introduced the Bebras model using ten years of observations in implementing the contest in different countries (Dagiene & Stupuriene, 2016). The main goal of the Bebras is to motivate pupils to be interested in informatics topics and to promote thinking which is algorithmic, logical, operational, and based on informatics fundamentals. The third largest cluster (#2) contains 17 articles with a silhouette value of 0.69, studying on ***mobile programming,*** mostly published around 2012. The most active cited to this cluster is Grover S. and Pea R with a review of the Computational thinking in K-12, which said that programming is not only a fundamental skill of CS and a key tool for supporting the cognitive tasks involved in CT but a demonstration of computational competencies as well (Grover & Pea, 2013). Other clusters are serious games, cognitive abilities, computational methods, computational problem solving, 21st-century competencies, lightbot, three-dimensional graphics and realism-virtual reality.

4. Conclusions and further research

According to the investigation of the intelligence cooperation, co-occurrence keyword, thematic research clusters, landmark articles, and bursting citations to references in CT study, we summarize some conclusions. First, it was mentioned in 1979 for the first time, but study began to emerge in 2009 and it entered a large-scale and rapid development stage since 2014, and it has been widely concerned. USA, China, and Spain are the top three countries of the CT researchers' quantity. Second, Computational thinking, education, k 12, programming, scratch are the top 5 keywords with high co-occurrence frequency. And Coding, game-based learning, programming and programming languages, k-12 education, computing, are the hot research topics in computational thinking. Third, the thematic clusters of computational literacy, contest, mobile programming reflect the most significant knowledge base clusters of computational thinking. In the early stages, research mostly has discussed definitions of CT in K-12 and high education. Now, the focus has recently shifted to tackling the more practical questions of how to cultivate and assess the CT skill. Although some strides have been made in the realm of defining curricula for cultivating computational skills and assessing students' progress, there still call for more empirical research on the cultivation and assessment of CS. And more cooperation among different countries or disciplines are needed.

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