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Review Article

Research Trends of Computational Thinking: A Bibliometric Review Over Three Decades

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Abstract
Currently, computational thinking is considered one of the future abilities that students must have. However, existing research has not offered comprehensive findings and explorations of computational thinking. This research presents bibliometric analysis research to investigate the development of research on computational thinking abilities at all levels of education. Specifically, the main aim of this research is to analyze trends in computational thinking research using bibliometric mapping based on variables: publications, citations, keywords, journals, authors, and countries. The initial search produced 5188 documents, which were then filtered into 1599 articles according to the inclusion and exclusion criteria. The first article recorded was from 1987 and the number of articles published increased in 2014-2022. This shows that the research trend in computational thinking has become a quite popular research topic in line with the awareness of the importance of computational thinking skills as one of the abilities that must be needed by the current generation. In relation to keywords related to computational thinking, discussion of computational thinking abilities is no longer limited to computer science or programming, but has spread to education, whether learning, assessment, or other supporting abilities. In addition, it is also identified the most productive journals in producing research on this topic, along with institutions and countries that have made major contributions to the related research. As the most productive country, the United States leads the list, followed by China and Türkiye. Overall, these results provide a broad picture of understanding regarding the development of computational thinking abilities that have been connected to various fields. Therefore, in the field of education, it is appropriate for policy holders to consider computational thinking skills to be integrated into the current curriculum.

Keywords: Bibliometric review, computational thinking, Scopus

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1. INTRODUCTION

Education plays an important role in the progress of a nation. A good education system can create superior human resources and improve the quality of life. Through education, an individual can cultivate their attitudes, skills, and intellectual capabilities to become a proficient, intelligent, and morally upright person. In line with the advancement of information technology, the world of education has also changed. One of the important skills needed today is computational thinking. Computational thinking skills are crucial for future generations in the 21st century, and they have achieved global recognition in recent years (Wei et al., 2020).

The term “computational thinking” was first coined by Papert in 1980 with the publication of his book.: “Mindstorms: Children, Computers, and Powerful Ideas”. The book ilustrates how computers can enhance cognitive processes and tranform the acquisition and application of knowledge (Yin et al., 2020). The term was later re-popularized by Wing in 2006 as a vital competence for prospering in the twenty-first century (Bedar & Al-Shboul, 2020). Guzdial in Tsai et al. (2021) defines computational thinking into two categories: domain specific and domain general. The specific domain is defined as the knowledge or skills needed to solve problems in computer science or computer programs, while the general domain is defined as the competencies needed to solve problems systematically in everyday life, such as in the thinking process. This demonstrates that computational thinking extends beyond the boundaries of computer science or programming, but rather encompasses how a person thinks when solving any problems they encounter.

Selby and Woollard (2013) identified five basic elements of computational thinking namely abstraction, decomposition, algorithmic thinking, evaluation and generalisation. Through computational thinking, students will understand how to observe problems, find solutions to problems, solve problems, and find and develop ways or solutions to problems. So important is computational thinking that Pea in Juškevičienė et al., (2021) asserts that computational thinking should be included into the education system as an essential learning objective to prepare students’ competence for future life.

However, it is apparent that the terminology and practical implementation of computational thinking skills are not widely understood among teachers and students in educational institutions (Ping et al., 2021). The fledging nature of the field of computatioanl thinking can give rise to intricate uncertainties when implementing it in education. Consequently, educators may lack familiarity with the concept of computational thinking skills and encounter challenges linking them to education syllabus (Shute et al., 2017).

1.1 Aim of the Study

Since 2006, greater focus on computational thinking has aided the development of computational thinking research (Tekdal, 2021). In this context, numeorus publications have been examined about computational thinking. To analyze the trends of computational thinking research, Tekdal (2021) conducted a bibliometric review using 321 articles of computational thinking produced in 2007 to 2021. To research gap from 2021 to recent years is the reason we conducted analysed the trends research of computational thinking, with the research questions (RQ) bellow:

RQ1: How many annual publications in this topic over last three decades?
RQ2: What are the most commonly used terms among researchers studying computational thinking?
RQ3: What are the highly cited documents in studies of computational thinking research?
RQ4: Who are the authors with the highest number of citations in computational thinking research publications?
RQ5: What are the most profilic journals in the field of research production?
RQ6: Which institutions and countries are the most productive in terms of publishing papers on computational thinking research?

2. METHODS

2.1 Study Design

This paper is intended to analyze research trends of computational thinking by using bibliometric mapping based on variables bellow: publication, citation, keywords, journal, author, institution, dan country. Bibliometric analysis is a methhod used to determine the current level of research activity in various fields and topic areas being explored by researchers (Tekdal, 2021). A five-step procedure was used to conduct scientific mapping, including bibliometric data, analysis, visualization, and interpretation (Zupic, 2023).

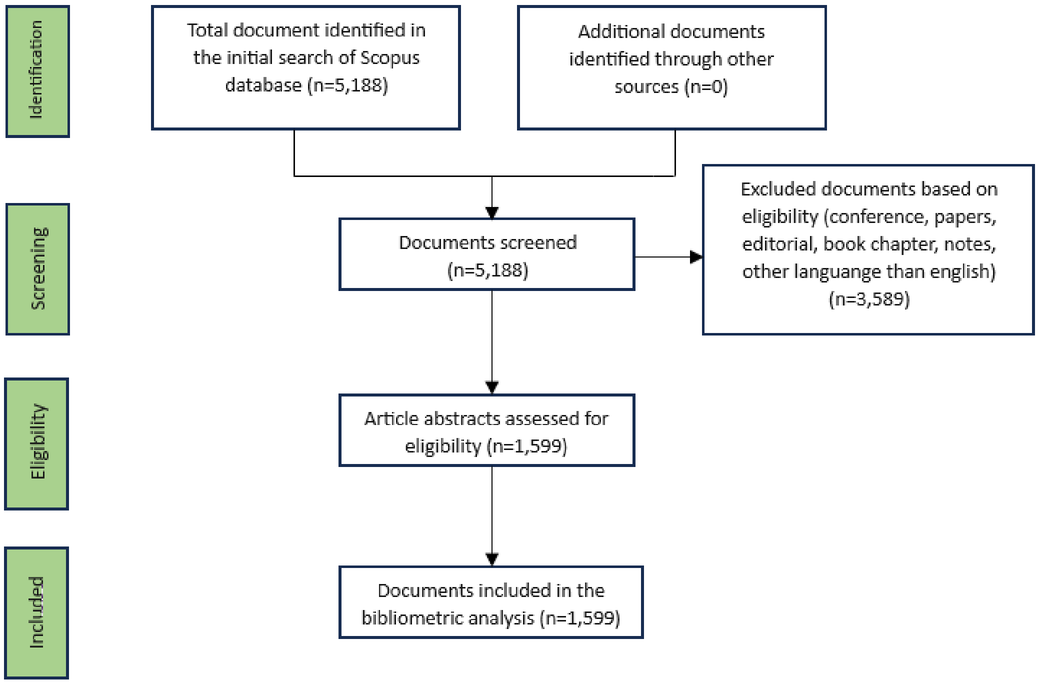

Figure 1. PRISMA Procedure

2.2 Data Collection

Bibliometric mapping analysis was conducted to investigate the published output concerning computational thinking. To collect the data, first we took relevant journals as the object of research. Research data were gathered from publications listed in the scopus database (https://www.scopus.com/) on 21 September 2023.

Scopus database has been considered as an adequate data source for the following reasons: 1) Relliable, up to date and boasts a greater number of recorded documents that alternative database (Khan et al., 2020; Trinh et al., 2022), 2)Publicy accesible with a university subscription and network (Akintunde et al., 2021), 3) Scopus provides 20% more extensive coverage than its primary rival, Web of Science (WoS), making it better suited for citation analysis (Maldonado-erazo, 2020), 4)Data extracted from scopus can be exported in a compatible format for most software utilize for bibliometric analysis (Gao et al., 2022), 5) It's covered over eighty-four million documents, seventeenteen point six million author profiles, twentyfive point eight thousand active peer-reviewed journal and seven thousand publishers (ELSEVIER, 2021). Therefore, using scopus as a database in bibliometric analysis allows researchers to get more presice and accurate data.

The primary search to find the data was using keyword: "Computational Thinking". These keywords are used because we want to get data about computational thinking generally, without being limited to certain types of subjects or levels of education. In the process of data search without limitating year, scopus database yielded 5188 documents from 1987-2023.

The bibliometric analysis was completed using Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) filter required data and as a guideline to provide an overview of computational thinking based on the literature review. PRISMA works based in the criterias bellow; Inclusion criteria: 1) Research articles should include the relevant keywordsin the title, abstract, or keywords section 2) Written in english, and exclusion criteria were: 1) Documents published in other languanges than english 2) Conference paper, editorial, book chapter, book coreection, and notes were not primary source. Figure 1 present the whole procedure for organize bibliometric mapping analyze based on PRISMA.

Total publications identified in the Scopus database were 5188. In this study, we only take article journals written in english and assessed for eligibility as primary source (30.82%), and it left 1599 articles for bibliometric analysis.

2.3 Data Analysis

To begin the data analysis process, we obtained journal articles as primary source from Scopus database and exported them into comma-separates value (csv) format. For analyze and visualization data, we used microsoft excel and VOSviewer software (version 1.6.18, Centre for Science and Technology Studies, Leiden University, Netherlands). Microsoft excel was utilised to present table, graphs, percentage, frequency data depending on variables used, and select decsriptive data. On the other hand, VOSviewer was employed to produce networks based on maps, providing visualisations and exploration the maps (Van Eck & Waltman, 2021). VOSviewer is also employed to analyse relationship and collaborations among highly cited authors, as well as coordinations between countries, keywords, institutions, and relevant knowledge pertaining to the chosen topic (Khan et al., 2020).

3. RESULTS

3.1 Publication and Citation Trends

One of the important indicators in determining development of a discipline, field, or topic is by looking at publication trends and research citations (Tekdal, 2021). The search result from scopus database was used as the primary source inform that there were 1599 articles published in 1987-2023 and the number is different each year. Figure 2 present the year-by-year trends in the distributions of publications and citations in computational thinking.

Figure 2 presents a compilation of publications related to computational thinking that have been published since 1987 until this data was captured. Research trends show a consistent improvement, both in the number of publications and citations. As can be seen from figure 2, the year 2022 had the greatest number of publications (n=352) and under 2007 had the lowest number of publications (n=1) in computational thinking. Study on computational thinking has been started in 1987 by Openshaw S.; Charlton M.; Wymer C.; Craft A. and it's become the first and the only one paper recorded in that year and has been cited 375 times. Figure 2 also summarizes computational thinking publications specifically incrising after 2016 (92.5% of total documents) and 2020 is the year with the greatest number of documents citation (n=4229). This incrising show that the study of computational thinking has received a positive response from academics in popularizing computational thinking at various fields of science. From Figure 2, it is evident that the determination value (R2) is 0.9124, indicating the reliability of the exponential trend line.

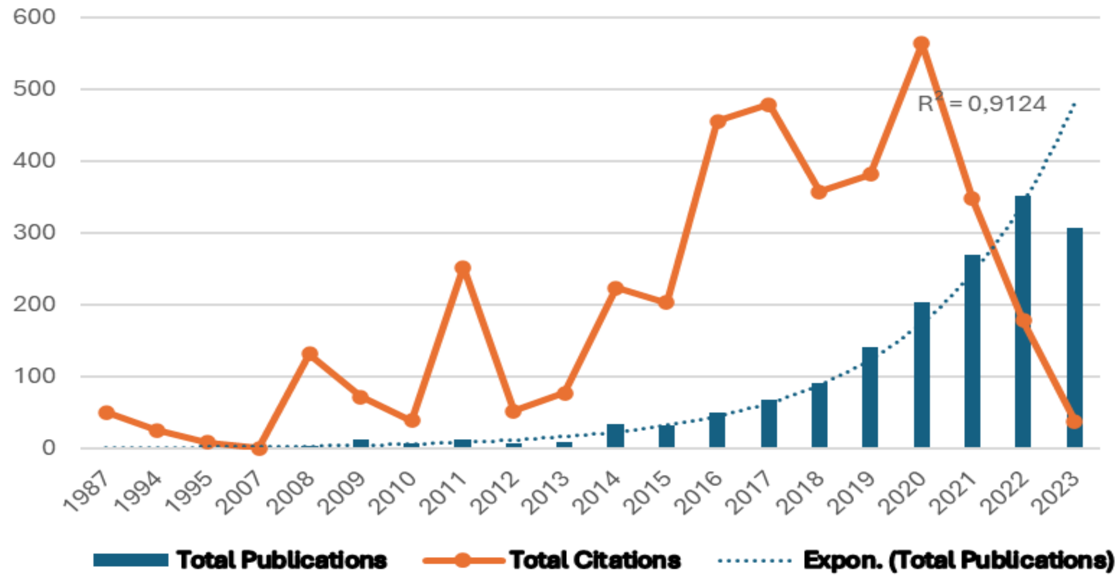

Figure 2. Annual Production of Computational Thinking Research

3.2 Most Used Keyword

VOSviewer was used for generating keyword co-occurance network and creating map that shows the words used in the title, abstract, and keywords. The threshold value was automatically set at 689 with 5168 keywords and a minimum of three occurences per keyword. Figure 3 shows an overlay visualization of the most frequently used keywords.

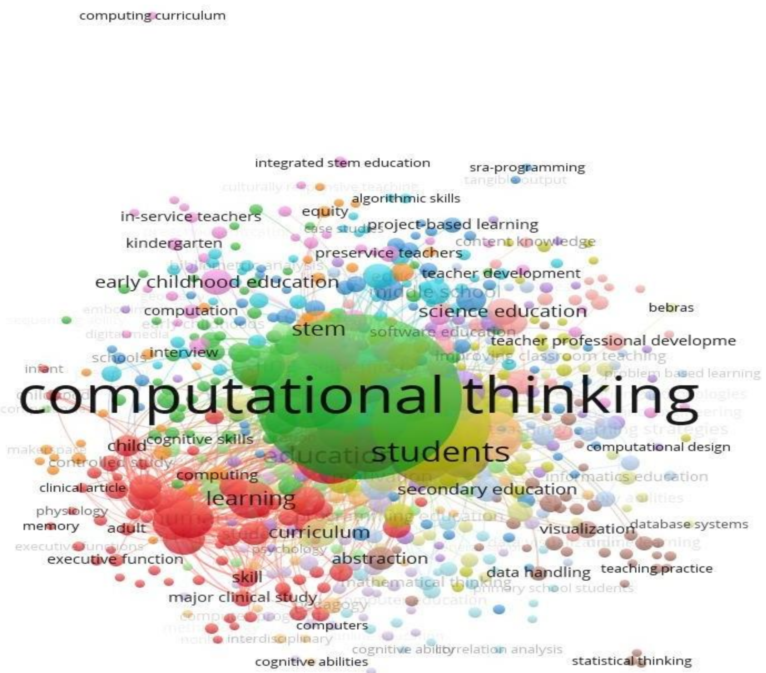

Figure 3. Overlay Visualization of Most Used Keywords

As shows at Figure 3, there were 16 clusters in this visualization map with the most frequently used keyword was "Computational Thinking" (1086 occurrences, 4657 total link strength). The green cluster at front of has the most used keyword "computational thinking", integrated with "coding", "scratch", and "robotics", "computer science", and "K-12 education". Second cluster where computational thinking is used include "education", "algorithm", "learning", and "problem solving" which make up the red cluster. Yellow cluster has keywords that appear frequently, namely "computational thinkings", "student", "learning system", "collaborative learning", and "motivation". Next cluster figured out with the orange one, which has "assesment", "constructionism", "mathematics education", and "stem". Only one interaction between "computational thinking" and "pre-service teacher", "teacher professional development", and "pedagogical content knowledge".

The top ten co-occuring keywords are presenting on Table 1.

Table 1. Most Used Keywords

Author Keywords	Occurences	Total Link Strength
Computational Thinking	1086	4657
Computational Thinkings	360	3269
Students	214	2142
Teaching	114	1167
Education	121	1109
Curricula	99	960
Human	58	910
Article	47	733
Programming	138	707
Education Computing	72	702

3.3 Most Highly Cited Documents

Table 2 presents the top fifteen cited documents over the years. The total number of the top- fifteen documents was 6815 which equal to 27.82% of total citations of all primary sources. Depending on Table 2, the Computational Thinking and Thinking About Computing is the most highly cited documents by having 975 citations. The second most cited document published in 2011 by Barr V and Stephen C, with the title Bringing computational thinking to K- 12: What is involved and what is the role of the computer science education community? and has been cited 972 times. Suprisingly, the first document records which published in 1987 by Openshaw S.; Charlton M.; Wymer C.; Craft A. become seventh-most cited document.

Table 2. Top 15 Most Cited Documents

Authors	Title	Journal	Cites
Wing J.M (2008)	Computational thinking and thinking about computing	Philosophical Transactions of the Royal Society A	975
Barr V.; Stephenson C (2011)	Bringing computational thinking to K-12: What is involved and what is the role of the computer science education community?	ACM Inroads	972
Weintrop D. et al. (2016)	Defining Computational Thinking for Mathematics and Science Classrooms	Journal of Science Education and Technology	713
Bers M.U. et al. (2014)	Computational thinking and tinkering: Exploration of an early childhood robotics curriculum	Computers and Education	546

Authors	Title	Journal	Cites
Lee I. et al. (2011)	Computational thinking for youth in practice	ACM Inroads	459
Román-González M. et al. (2017)	Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test	Computers in Human Behavior	394
Openshaw S. et al. (1987)	A mark 1 geographical analysis machine for the automated analysis of point data sets	International Journal of Geographical Information Systems	375
Sengupta P. et al. (2013)	Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework	Education and Information Technologies	344
Hsu T.-C. et al. (2018)	How to learn and how to teach computational thinking: Suggestions based on a review of the literature	Computers and Education	339
Atmatzidou S.; Demetriadis S (2016)	Advancing students' computational thinking skills through educational robotics: A study on age and gender relevant differences	Robotics and Autonomous Systems	315
Sáez-López J.-M. et al. (2016)	Visual programming languages integrated across the curriculum in elementary school: A two year case study using "scratch" in five schools	Computers and Education	303
Yadav A. et al. (2014)	Computational thinking in elementary and secondary teacher education	ACM Transactions on Computing Education	295
Voogt J. et al. (2015)	Computational thinking in compulsory education: Towards an agenda for research and practice	Education and Information Technologies	291
Aho A.V (2012)	Computation and computational thinking	Computer Journal	254
Korkmaz Ö. et al. (2017)	A validity and reliability study of the computational thinking scales (CTS)	Computers in Human Behavior	240

3.4 Most Productive Authors

The top-fifteen productive authors with the greatest number of publications related to computational thinking is informed in Table 3.

Table 3. Number of Publications in The Top 15 Productive Authors

Author	Institution	Country	N	H-Index
Yadav, A.	Michigan State University	USA	14	33
Hsu, T.C.	National Taiwan Normal University	Taiwan	14	21
Kong, S.C.	The Education University of Hong Kong	Hong Kong	12	22
Bers M.U.	Boston College	US	12	36
Román-González M	Universidad Nacional de Education a Distancia	Spain	11	17
Sun, L.	Minzu University of China	China	10	7
Yang, W.	The Education University of Hong Kong	Hong Kong	9	17

Author	Institution	Country	N	H-Index
Wong, G.K.W.	The University of Hong Kong	Hong Kong	9	13
Weintrop, D.	University of Maryland	US	9	21
Osman, K.	National University of Malaysia	Malaysia	9	28
Looi, C.K.	Education University of Hong Kong	Hong Kong	9	34
Zhou, D.	Beijing Normal University	China	8	6
Lee, V.R.	Standford University	US	8	20
Korkmaz, Ö.	Amasya Universitesi	Türkiye	8	11
Kalogiannakis, M.	University of Crete	Greece	8	30

From the Table 3, Yadav A. and Hsu, T.C. had the most publications with 14 articles, followed by Kong, S.C. and Bers, M.U. with 12 articles, and Román-González M with 11 articles. The remaining autros from thetop-fifteen were Zhou, D., Lee, V.R., Korkmaz, Ö., and Kaloginnakis, M. with 8 articles. Table 3 also shows the most profilic author by h-index. The H-index is a numerical assesment of the scientific productivity of a researcher againts the documents they publish in the scopus databas (Hirsch, 2005). The top-five authors with the biggest number of n-index were Bers M.U. (36), Looi, C.K. (34), Yadav, A. (33), Kalogiannakis, M. (30), and Osman, K. (28). In addition, articles written by USA researchers had the greatest number of publications (n=43), following by Hong Kong (30) and Taiwan (14).

Figure 4. Author Collaboration Network

The collaboration network underwent analysis using the VOSviewer tool, with a minimum of 3 documents authored and at least 10 citations required. Figure 4 informs the whole collaboration network of 1516 authors with 10 meet thresholds. Figure 4 ilustrates the existence of 10 collaboration clustres, each with a distinct colour. Each cluster mostly has the same node size and disconnected one another. Analyzing Figure 4, it can be informed that the main cluster has two authors: Israel-

Fishelson, R and Hershkovitz, A. with pink node. Second cluster includes two authors: Kanaki, K. and Kalogiannakis, M, with green node, and third cluster represent by blue node with consist of two authors: Kong, S.C. and Lai, M.

3.5 Most Active Journals

Table 4 bellow figure out top-fifteen most profilic journals, number of publications, h-index, scopus quartile, scimago journal rank (SJR) and publisher.

Table 4. Top 15 Most Active Journals

Journal	N	H-Index	Q	SJR 2022	Publisher
Education and Information Technologies	95	61	Q1	1.25	Kluwer Academic Publishers
Journal of Educational Computing Research	55	70	Q1	1.67	SAGE
Informatics In Education	43	26	Q1	0.65	Institute of Mathematics and Informatics
Computers And Education	41	215	Q1	3.68	Elvesier
Journal Of Science Education and Technology	33	74	Q1	1.28	Springer Netherlands
Interactive Learning Environments	33	57	Q1	1.17	Taylor and Francis
Computer Science Education	32	38	Q1	0.94	Taylor and Francis
International Journal of Child Computer Interaction	31	33	Q1	1.07	Elvesier BV
Computer Applications in Engineering Education	28	37	Q1	0.65	John Wiley & Sons
Education Sciences	27	40	Q2	0.61	MDPI AG
Sustainability Switzerland	25	136	Q1	0.66	MDPI AG
Educational Technology Research and Development	24	101	Q1	1.52	Springer
Thinking Skills and Creativity	23	58	Q1	1.15	Elvesier BV
Techtrends	22	48	Q1	0.8	Springer New York
Frontiers In Psychology	22	157	Q2	0.89	Frontiers Media S.A.

Based on the Scopus database, 464 different journlas contributed to the relevant literature. The top- fifteen jurnal publishet 534 articles, sharing 33.4% of total articles. From Table 4, we can summarize that Education and Information Technologies journal was the most active journal source with 95 articles and 1419 citations over the year 1987-2023. Second rank was Journal of Educational Computing Research with 55 articles and Informatics in Education with 43 articles. The study revealed that the Computers and Education journal attained the highest h-index (215), with Frontiers in Psychology following suit (157). These results imply that these three journals have had a remarkable impact on computational thinking. When ranked by scimago journal rank (SJR), the Computers and Education journal had the maximum score (3.68), the second journal was Journal of Educational Computing Research (1.67) and the third rank was Educational Technology Research and Development (1.52). Table 4 also figure out journals based on Q- score. The Q-score is an objective analytical tool that identifies the ranking of scientific journals based on the sceintific groups they belong to and their impact factors (ASAN & ASLAN, 2020). The highest Q-score, the most impactful to the topic research (Irwanto, Wahyudiati, Saputro, & Laksana, 2023). As a result, there only two journals (Education Sciences and Frontiers in Psychology) had Q2 (13.3%), and the rest journals had Q1 (86.7%). Therefore, we can conclude that most of the top fifteen journals (13 articles) had a great impact to the topic research. Other information that can be senn from journals, was the most active publisher in publishing journals about computational thinking. The publishers were Elvesier Ltd., Taylor and Francis Ltd., and MDPI AG with 2 types of journals.

3.6 Most Productive Institutions

The most productive institutions are summarized in table 5. The top fifteen universities participated in 18.63% of the total publications. The top three institutions are National Taiwan Normal University (Taiwan; 28 publications), The education University of Hong Kong (Hong Kong; 27), and The University of Hong Kong (Hong Kong; 26).

Table 5. Top 15 Most Productive Institutions

Institution	Country	Types	N
National Taiwan Normal University	Taiwan	Public	28
The Education University of Hong Kong	Hong Kong	Public	27
The University of Hong Kong	Hong Kong	Public	26
Michigan State University	US	Public	22
NC State University	US	Public	21
Nanyang Technological University	Singapore	Public	21
Universiti Kebangsaan Malaysia	Malaysia	Public	20
National Institute of Education	Singapore	Public	18
Beijing Normal University	China	Public	18
Vilniaus Universitetas	Lithuania	Public	18
Purdue University	US	Public	17
University of Maryland, College Park	US	Public	16
Universidad Nacional de Educacion a Distancia	Spain	Public	16
Utah State University	US	Public	15
Jeju National University	South Korea	Public	15

The fifteenth rank institutions had 15 articles published. Five of the top active institutions are located in USA, two in Europe (Spain and Lithuania), and the rest were located in Asia. This implies that computational thinking was one of popular topic research in Asia. Interestingly, all top-fifteen institutions that played dominant role in computational thinking research were public universities. The most prolific institution in microlearning is the University of Wollongong, Australia with 25 documents. The second was The University of Queensland Business School, Australia with 16 documents. There are non-university institutions. Commonwealth Scientific and Industrial Research Organisation with 8 documents and CSIRO Data16 with 7 documents.

3.7 Most Productive Countries

Table 6 bellow represent top-fifteen countries with the highest number of published articles.

Table 6 identified that the top-fifteen countries contributed 1379 articles, or 86.24% of total articles. United States lead with hignhest number of papers (481), followed by China at second rank (131) and Turkey at third rand with 113 articles. Indonesia and Finland had same number of articles published (32), and not much differ than Norway in the last rank with 31 articles. If the countries above were grouped by region, 517 articles were published in America, 104 in Southern Europe,

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145 in Western Europe, 63 in Northern Europe and 550 articles were published in Asia. In Asian context, China is the country that published the most.

Table 6. Top 15 Most Productive Countries

Country	N of Papers	%
United States	481	30
China	131	8
Türkiye	113	7
Spain	99	6
Taiwan	93	6
South Korea	74	5
Hong Kong	57	4
Greece	55	3
Malaysia	50	3
Italy	49	3
United Kingdom	46	3
Canada	36	2
Indonesia	32	2
Finland	32	2
Norway	31	2

We also analyzed co-authorship relation beetween countries that presented in figure 5. When the threshold was set at 5 minimum documents it was given automatically 9 clusters form 90 countries involved. The largest cluster (red node) consist of nine countries with Germany leading the group (25 documents, 213 citations, and 29 total link strength). Second cluster (green node) consist of eight countries, and it was led by Spain with 100 articles, 2197 citations, and 41 total link strength. The third cluster represent by yellow node had six countries and led by China with 130 articles, 1236 citations, and 65 total link strength.

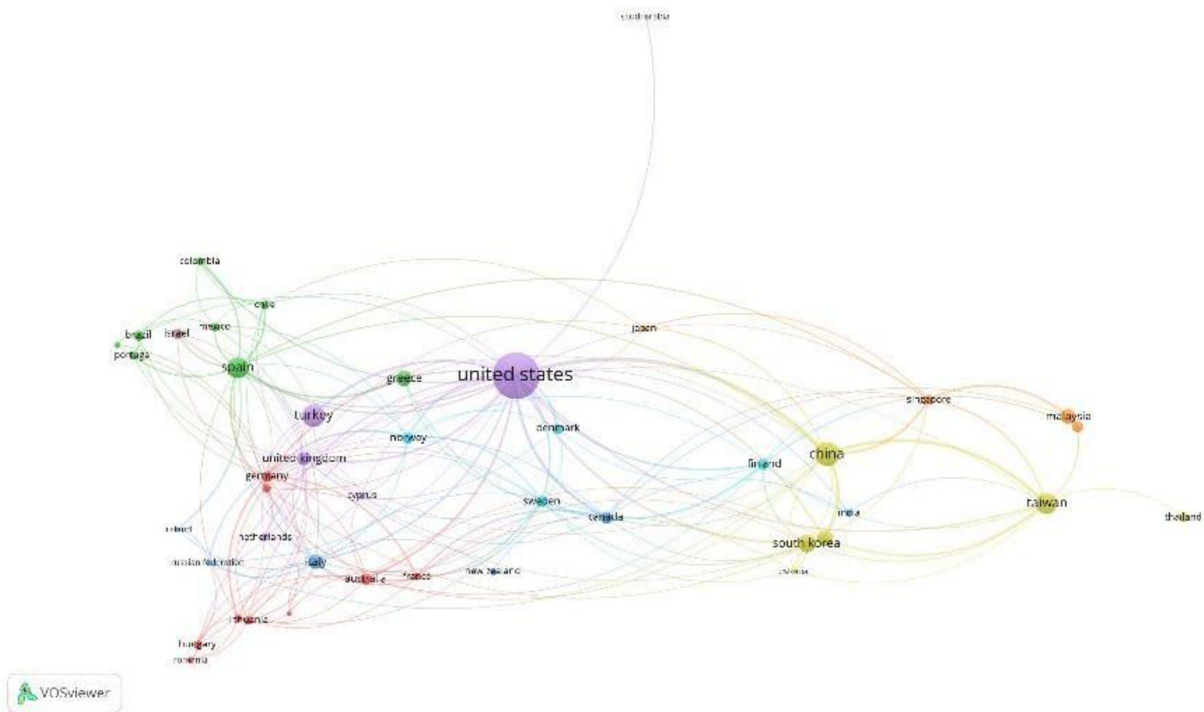

Figure 5. Collaboration Network of Countries

4. DISCUSSION

This paper examined research trends of computational thinking based on scopus database through bibliometric analysis. There were 1599 documents from 1987-2023 retrieved and has been assesed with inclusion and exclusion criteria that mentioned above. From the scopus database, it can be known that the first document recorded was published in 1987 by Openshaw S.; Charlton M.; Wymer C.; Craft A. Then in 1994, 1995 and 2007 there was no rapid progress, where only one article was published that year. This shows that under 2007, computational thinking was not an interesting topic in researsh materials.

The growth trends of computational thinking begin in 2014 and continues to increase every year until now. This indicates that the more incrising number of publications, the more tendency of growing interest in this research area. This finding was as same as what was done by Tekdal (2021). In particular, a significant rise in the quantity of documents took place from 2019 to 2022. The peak number of publications was reached in 2022 with 352 articles. The two top articles published in 2022 were written by Ezeamuzie, Ndudi O.; Leung, Jessica S. C.; and Tsarava, Katerina, et all. First article has a title *"Computational Thinking Through an Empirical Lens: A Systematic Review of Literature"* which providing an overview of the diverse approaches to computational thinking based on 81 empirical studies and proposes an algorithmic-focused model that increase conceptual clarity beetwen computational thinking and programming (Ezeamuzie & Leung, 2022). The second one was discussed about examining reliability of computational thinking assessment for primary school. Additionally, it was discovered that there is a favourable correlation between computational thinking and intricate numerical abilities, oral reasoning, and non-verbal visual-spatial abilities (Tsarava et all, 2022). This shows that generally, discussions about computational thinking are no longer limited to computer science and programming but also integrated into education, both in learning, assessment, and other supporting abilities.

In addition, the most keywords used were "Computational Thinking" (1086 occurrences, 4657 total link strength), integrated with "coding", "scratch", and "robotics", "computer science", and "K-12 education". It's assumed that these articles focus on relation between computational thinking and those keywords. Integrating basic coding in the curriculum could enlarge and train the learner's general and higher-order thinking skills such as problem deconstruction, analyse, and evaluation, which play a dominant role in problem solving and as part of computational thinking skills (Ching et al., 2018). Scratch and Alice 2.4 applications can be used as game-making projects for evaluating computational thinking processes (Allsop, 2019). Computational thinking can be developed through educational projects in the fields of chemistry and robotics, by conducting experiments through games and activities (Tarrés-Puertas et al., 2022).

Second cluster where computational thinking is used include "education", "algorithm", "learning", and "problem solving" which make up the red cluster. Computational thinking ability is one of the 21st century skills that must be developed for future generations and has been recognized globally in recent years (Wei et al., 2020). It can be assumed that integrating computational thinking into our curriculum today is necessary. Incorporating various programming resources, including PseInt, CodingBat, and the Python turtle graphic library, alongside computational thinking practices, can enhance students' comprehension and skill development in programming concepts, as well as related abilities such as abstraction and algorithmic thinking (Laura-Ochoa & Bedregal-Alpaca, 2022). As the conclusion, we may see computational thinking has merged into various fileds of scientific discipline and at the same time indicates that researchers have studied this field more seriously.

Only one interaction between "computational thinking" and "pre-service teacher", "teacher professional development", and "pedagogical content knowledge". It shows that computational thinking research related to these keywords is not commonly conducted. Whereas in this case the teacher has an important role in building a good learning environment and developing students' critical abilities in every element of learning. Teacher training programmes are important to ascertain that pre-service teachers are equipped with the necessary skills and knowledge to teach (Bal et al., 2022). So, it is fitting that pre-service teachers are also equipped with the thinking skills of this century, especially computational thinking skills. This also provides a great opportunity for researchers to explore deeper into computational thinking research related to these keywords.

In terms of highly cited documents, Wing J.M. had highly cited documents (975 times). In this research, Wing J.M stated computational thinking as an analytical approach to problem solving, system design, and understanding human behaviour. It will affect everyone in every area of business and poses new educational challenges for society (Wing, 2008). The second most cited document published in 2011 by Barr V and Stephen C, with the title *Bringing computational thinking to K- 12: What is involved and what is the role of the computer science education community?* and had been cited for 972 times. Current research explores the potential of computer science education to encourage collaborative computational thinking within K-12. The study has identified crucial computaional thinking skills, including data gathering, analysis, representations, problem dissection, abstraction, algorithms, procedures, automation, parallelization, and modelling (Barr & Stephenson, 2011). Then, the next rank was Weintrop D.; Beheshti E.; Horn M.; Orton K.; Jona K.; Trouille L.; Wilensky U. had 713 cited times. The article suggests that computational thinking is a next generation science standard. To address this, it identifies computational thinking in mathematics and science classes using a taxonomy form. This form includes data practices, modelling and simulation practices, computational problem solving, and systems thinking activities (Weintrop et al., 2016). The quality of literature can be measured by the frequency of citations it receives. Papers of a higher quality are more likely to be cited (Patterson & Harris, 2009). Depending on that, these three articles were high-quality article and had an important impact in this research area.

Regarding the most productive author, Yadav, A. and Hsu, T.C. had the most publications with 14 articles, followed by Kong, S.C. and Bers, M.U. (12), and Román-González M (11). The remaining authors from the top-fifteen were Zhou, D., Lee, V.R., Korkmaz, Ö., and Kaloginnakis, M. with 8 articles. This is similar of what was found by Rafiq et al. (2023). Yadav A, as the most author has done a lot of research about computational thinking related to teacher education, teaching or learning strategies, science, and metacognitive strategies. Yadav's two most cited articles related to computational thinking skills are describing about the use of computational thinking modules in pre-service teachers and giving a new insight about the importance of computational thinking for other disciplines such as arts and English, and is not limited to computer science, maths, and science (Yadav et al., 2014), and the key to transforming students from simply being technologically literate to using computational tools to solve problems by developing teachers' perceptions of computational thinking, by engaging students and administrators in creating processes that can be automated, and by looking for ways to incorporate computational thinking ideas into curriculum and practice, as well as highlighting the relationship of computational thinking to curricular contexts

(Yadav et al., 2016). Both articles highlight and illustrate that computational thinking is no longer limited to computing or science, but also to other disciplines. The teacher has a central role to play in organising a learning environment that is appropriate for embedding computational thinking skills into the material or learning activities. We also analyzed the collaboration network to investigate the collaboration between researchers. The result shows there were 10 collaboration clusters disconnected from one another. As a summary, we can conclude that the cooperation between computational thinking's researchers is not srongly enough because there're only a small groups cluster that disconnected each other.

With regard to productive sources, the *Education and Information Technologies* had the highest number of publishing with 95 documents. The next rank was followed by Journal of Educational Computing Research (55 documents) and Informatics in Education (43 documents).

The possibly reason for the highest number publication of *Education and Information Technologies* had wide aims and scope. As mentioned in https://www.springer.com/journal/10639/aims-and-scope, this journal proposed to provide perspective view at all levels, from the micro level such as pedagogical approaches into macro issues sucah as national policies, from pre-school to college, and from administrators to researchers. Furthermore, in comparison to the second most productive sources, the *Journal of Educational Computing Research*, *Education and Information Technologies* commenced its first release in 1996, whereas the *Journal of Educational Computing Research* began in 1990. Nevertheless, the *Journal of Educational Computing Research* produces only 2-3 publications per year on average, while *Education and Information Technologies* produces 3-11 journals annually. This rise in publications has been significant over the past two years, with 9 publications being published in 2022 and 11 publications in 2023.

The Q-score of most-fifteen active journal were Q1(n=13 documents; Q- score = 86.7%) and Q2 (2 documents; Q-score = 13.3%). Q1 score means the best quartile journa score. The highest Q-score, the most impactful to the topic research (Hirsch, 2005). Therefore, we can conclude that most of the top fifteen journals (13 articles) had a great impact to the topic research.

According to the most productive institutions, National Taiwan Normal University had the highest number of publications (28 publications). It was followed by The Education University of Hong Kong (27 publications), and The University of Hong Kong (26). Regarding country, two active institutions are in USA, two in Europe (Spain and Lithuania), and the rest were located in Asia. This implies that computational thinking was one of popular topic research in Asia. It can be done due to their dominance in the ICT sector, countries including Korea, Taiwan, HongKong and China have initiated national curricular overhauls to tackle the current computational thinking education advancement in K-12 education (So et al., 2020). Computational thinking skills have been researched and employed in the field of education in the United States, including through the FACT (Foundations for Advancing Computational Thinking) program developed for high schools by Stanford University and Scalable Game Design (SGD) at the University of Colorado, Boulder, which produced tools such as AgentSheets and AgentCube. These tools enable users to create their own agent-based games and simulations using a user-friendly drag-and-drop interface, promoting the learning of Computer Science concepts, logical reasoning and algorithmic thinking among students (Lockwood & Mooney, 2018).

Concerning about productive countries, we found that United States lead with highest number of papers (481), followed by China at second rank (131) and Turkey at third rand with 113 articles. Similar findings were also found at previous study held by Tekdal (2021), who found that USA published 33 articles or 23.74% of total documents. The US is considered the most productive nation due to its significant research budget, which totalled $171.26bn in research and development across the Federal Government in Budget 2022, signifying a 9% increase from the previous year (https://www.whitehouse.gov/). The availability of such a substantial funding budget stimulates innovation in R&D, which, in turn, influences the country's economic, educational, and technological progress. Thus, if the countries above were grouped by region, 517 articles were published in America, 104 in Southern Europe, 145 in Western Europe, 63 in Northern Europe and 550 articles were published in Asia. In Asian context, China is the country that published the most. Based on the co-authorship relation beetween countries, it was found that United States had the most affiliations with other country, with 30 link and 108 total link strength and followed by China with 13 link and 65 total link strength.

5. CONCLUSIONS AND LIMITATIONS

Computational thinking skills are widely acknowledged as essential competencies for today's generation. They allow students to comprehend problems, identify solutions and implement them to tackle complex challenges. Accordingly, research on computational thinking skills is expanding. This is exemplified in the findings of bibliometric analysis from this study, which analysed 1599 articles extracted from the Scopus database on 21 September 2023. Since the publication of the initial article on computational thinking by Openshaw S.; Charlton M.; Wymer C.; Craft A in 1987, there has been an upward trend observed in this field. The most significant increase took place during 2019-2022, with Yadav, A. and Hsu, T.C being the most prolific authors in this area.

Computational thinking research is commonly linked with coding, scratch, robotics, education, algorithms, learning, and problem-solving. It is no longer confined to computer science and science. The linguistic learning sector has also adopted the computational thinking approach. Here, the Unified Modelling Language (UML) is converted into a teaching instrument to enhance problem-solving skills that are related to computational thinking principles (Rottenhofer et al., 2022). To enhance computational thinking through education, teachers must be provided with a thorough understanding and changing of their perceptions so that they are able to integrate the idea of computational thinking into practical learning. The anticipated outcome is a transformation amongst students from being technology-literate to adept at using computational tools to address complex problems. This type of innovation is comparable to what has been incorporated in Foundations for Advancing Computational Thinking (FACT) through the implementation of curriculum in secondary schools.

In conclusion, the trend of research related to computational thinking continues to grow and spread into the field of education and is no longer limited to computing, mathematics or science. This change in perception should be understood thoroughly so that its integration in practical learning has a great opportunity.

Due to limitatios of this research where author only using scopus database and data retrieved on 21 September 2023. There are several implication and future research that might be carried out, such as: 1) Using other database as a primary source to gain more relliable data 2) New studies can prioritize collaboration between researchers and 3) Research on computational thinking mostly carried out student from primary to secondary school. In this context, it might be expanded to higher education to fill the gap.

Conflict of Interest

The authors declare no conflict of interest.

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