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Bibliometric Analysis of Educational Research on Coding Listed in Web of Science with Vosviewer

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The 21st century is often referred to as the digital age due to the rapid development of technology. As technology advances, people's needs, behaviors, and lifestyles are also evolving. To keep pace with these changes, individuals must acquire certain skills that are considered essential for the 21st century, one of which is coding. Many countries have incorporated coding education into their curricula to help students develop these skills. However, with the growing volume of research on coding, reviewing and analyzing the increasing number of studies has become more challenging, necessitating the use of bibliometric methods. This study focuses on educational research related to coding (programming) published in the Web of Science (WOS), using an innovative bibliometric analysis approach. A review of the literature revealed that the terms "coding" and "programming" are often used interchangeably. Therefore, the research was narrowed down to educational studies that included the keywords "coding" or "programming" in the title, as listed in WOS. By October 2023, a total of 20,519 studies were identified. Through this analysis, the current state of educational research on coding was examined, highlighting the contributions of authors, institutions, and countries to the field. Data analysis was conducted using the VOSviewer program, which supported various methods such as citation analysis, co-authorship analysis, keyword analysis and bibliographic coupling analysis. The results were organized under several headings, and recommendations were made based on the findings.

INTRODUCTION

In order for individuals to keep up with the digital age, they need to have skills called 21st century skills. The said set of skills include life and career skills, critical thinking, communication, collaboration, creativity, problem solving, technology skills, digital literacy and computational thinking. Although the skills that individuals should have in the 21st century are classified under different names in the literature, it is seen that they refer to

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similar concepts (Yıldız et al., 2017). Computational thinking is also recognized as an ideal tool for developing 21st century skills (Grover & Pea, 2013).

Although Papert (1980) first described the idea of computational thinking, it started to become popular after (Wing, 2006). Wing (2017) argued that computational thinking is a skill that every individual of all ages should have as a basic skill in the 21st century. Organizations such as the International Society for Technology in Education (ISTE), the National Research Council (NRC), and the Computer Science Teachers Association (CSTA), as well as giant technology companies (Google, Microsoft, etc.) have an important place in supporting Jeannette M Wing's idea of computational thinking as a 21st century skill (Durak & Saritepeci, 2018). Hsu et al. (2018) stated that computational thinking is widely valued by researchers and plays a key role in achieving future educational goals.

Coding (Programming) Education

Wing stated that computational thinking should be at the central point of the K-12 curriculum and called for research on effective ways to teach computational thinking skills to students. After this call, computational thinking has attracted the attention of educators and educational researchers (Tang et al., 2020). Kong (2016) mentioned in his study that a curriculum should be designed in K-12 to develop computational thinking skills through coding (programming) and that the next generation should be raised as creators and problem solvers. Many countries around the world have updated their curricula to develop these skills and added coding (programming) education to their curricula (Nouri et al., 2020). Education systems around the world have recognized the importance of coding (Wu et al., 2020). It can be said that coding education is a good option to develop computational thinking skills (Sayın & Seferoğlu, 2016).

Coding can contribute to the development of skills such as computational thinking creativity, collaboration, technology literacy and flexibility. It allows them to use mental processes more actively. With coding, individuals can learn to produce different solutions while solving the problem, which can gain creative thinking skills (Haymana & Özalp, 2020). It can also strengthen problem-solving skills by solving complex problems in a systematic way by breaking them down into parts. Coding helps children understand and effectively use technology. Individuals with coding skills at an early age will be more advantageous in the business world of the future (Chen et al., 2017). Since coding projects often require teamwork, individuals learn to share, communicate and collaborate.

Seymour Papert, one of the pioneers of early coding education, is known for his development of the Logo programming language to teach children the basics of coding. This language has enriched learning experiences by giving children the opportunity to develop problem solving, creativity and analytical thinking skills. Papert allowed students to explore their own world using the power of the computer (Papert, 1980). His student Mitchel Resnick, on the other hand, aimed to provide students with creative thinking and problem-solving skills by gamifying learning. One of Resnick's most well-known contributions is the visual programming language called Scratch. Scratch allows children to understand programming concepts in an interactive environment, allowing them to develop creative thinking, collaboration and problem solving skills (Resnick et al., 2009). Mitchel Resnick's efforts have contributed to students' adaptation to the digital age by making coding education more attractive and accessible. Seymour Papert's development of the "LOGO" programming language and Mitchel Resnick's development of Scratch, a block-based programming

language, contributed greatly to the early introduction of coding education (Bers, 2018).

According to the European Schoolnet report, 17 countries of the European Union (EU) have included coding education in their education curricula (Balanskat & Engelhardt, 2014). In the UK, coding education was made compulsory in schools in 2014 within the framework of the "National Curriculum for Computing" (Williamson, 2017). In the UK, coding lessons are taught with "Scratch", a visual and block-based programming language, and "Python", a text-based programming language, at the advanced level to provide students with basic programming skills (Dorling & White, 2015). In addition, coding education is encouraged through various programs and initiatives. In Germany, many universities, technical schools and various institutions offer coding education through computer science and software engineering programs.

India, one of the world's largest software exporters, attaches great importance to coding education (Akdemir & Nurbay, 2020). In Estonia, computer and coding skills are taught in all schools with a program called "ProgeTiger" (Cabrera Delgado, 2015). Finland includes coding in its education programs for the acquisition of digital skills. Students learn basic coding skills through hourly coding lessons called "Coding Hour" (Koodaustunti). In South Korea, a coding education program focuses on the development of computational thinking skills (Kim & Kim, 2018).

In Türkiye, the importance given to coding education is gradually increasing. In addition to the courses given in schools in Türkiye, the "Code Week Turkey" project is carried out in order to contribute to and popularize coding skills at an early age. According to EU code week data, Türkiye is the country with the highest number of activities with 23885 activities in 2023 (Codeweek.eu, 2024).

In the digital age, coding skills have become an important skill required not only for software developers but for everyone (National Research Council, 2010). Individuals with coding skills can keep up with technological developments. Unleash their creative potential and realize innovative ideas. They can transform an idea into a concrete product. For this reason, the subject of coding maintains its importance today. Studies on coding provide important information to evaluate the effectiveness of coding education, to contribute to the development of educational policies, to make learning processes appropriate and to strengthen individuals' digital skills.

Bibliometric Analysis

Studies on coding are increasing day by day and it is becoming more and more difficult to analyze this information. At this point, bibliometric analysis methods have become an important tool for analyzing big data, discovering trends in research, visualizing research topics and providing us with the overall picture (Ellegaard & Wallin, 2015). In other words, bibliometrics is a method that provides numerical analysis of the relationships between the studies produced by authors in a particular field (Ulakbim Cahit Arf Information Center, 2023).

Bibliometric analysis is a field of research that examines studies in the scientific literature and the relationships between these studies. This type of analysis is usually conducted using bibliographic data to assess, track and understand scientific production in a particular subject, discipline or research area. Bibliometric analysis is an integral part of research evaluation (Ellegaard & Wallin, 2015). The increase in the number of studies in the literature

necessitates some measurement tools. Alan Pritchard first used the term bibliometric used in research evaluation methodology. However, its use and application can be traced back to the 1890s (Osareh, 1996; Sengupta, 1992). Bibliometric analysis, books, journal articles, etc. It can be defined as the quantitative analysis of large bibliographic units such as (Broadus, 1987). Bibliometrics journals, institutions, countries etc. It is very useful for classifying information according to different variables such as (Merigó et al., 2015).

Web of Science

The first step for bibliometric analysis of educational research on coding is to decide on the appropriate data source for our research area. Nowadays, there are many bibliographic databases such as PubMed, SpringerLink, Google Scholar, Scopus, Web of Science, etc. However, not all of them allow us to download the necessary data for analysis. Therefore, we need to choose the database from which we can download bibliographic data (Moral-Munoz et al., 2020). Web of Science (WOS) is a bibliographic database that allows us to download bibliometric data. WOS is a bibliographic database that contains many databases (SCI-E, SSCI, A&HCI, etc.) and provides citation data that provides access to them (Falagas et al., 2008). Founded in 1960 as the Scientific Information Institute (ISI), WOS was founded in 1997 by Dr. Eugene Garfield. Today, Clarivate Analytics owns WOS (Li et al., 2010). WOS is a bibliographic database and research evaluation tool used to track scientific research and access academic information. This database provides us with a global archive of studies in educational sciences, social sciences, health sciences, science, technology and different fields. Therefore, WOS has become an important resource for academics, researchers, scientists and students to conduct literature searches, and develop research projects.

VOSviewer

Bibliometric software tools are needed to analyze the data obtained from WOS. VOSviewer is a software tool for scientific mapping with a great visualization that can perform big data analysis (Moral-Munoz et al., 2020). VOSviewer is a scientific mapping software designed for visualization of bibliometric data. VOSviewer software supports major databases (Web of Science, Scopus, Dimensions, Lens, PubMed). Nees Jan van Eck and Ludo Waltman developed VOSviewer in 2009. Erasmus University Rotterdam supported previous versions of VOSviewer. VOSviewer is a java-based program. VOSviewer is supported by many operating systems and can also be used directly via the internet (van Eck & Waltman, 2010).

Purpose and Importance of the Research

Examining the increasing number of studies on coding is becoming more and more difficult day by day. For this reason, bibliometric methods were needed. Bibliometric methods have proven to be effective in evaluating the academic performance of academic studies and performing numerical analysis, thanks to information such as their relationships with each other, how often they are cited, and which studies are influenced by them.

Bibliometric analyses performed with VOSviewer are used to analyze and visualize scientific studies. VOSviewer is of great importance in revealing the relationships between studies and making complex datasets understandable. VOSviewer allows us to create a network graph of published studies on any subject and observe the relationship between studies. The impact of one study on other studies can be seen and important studies can be identified. Research trends can be identified, keywords used in studies can be analyzed, collaborating authors can

be identified, and new studies on the subject can also be accessed. Therefore, these analyses can make important contributions to institutions, researchers and policy makers.

There are many studies on coding, but studies such as systematic review, content analysis, meta-analysis are limited. There is no study in the literature that performs bibliometric analysis with VOSviewer software tool for educational research on coding. Since fewer articles can be examined in content Analysis, systematic analysis or meta-analysis studies compared to bibliometric analysis, bibliometric analysis methods are needed.

The aim of this study is to conduct a bibliometric analysis of educational research on coding, to reveal its current status, to provide a basis for future research and to contribute to educational policies.

In this study, we analyzed the educational research on coding listed in WOS:

(1) What are the featured authors, institutions and countries/regions?
(2) How is the citation analysis?
(3) How is the co-authorship analysis?
(4) How is the analysis of keywords?
(5) How is the bibliographic coupling analysis?

Answers to these questions were sought. The data obtained are presented in the findings.

METHOD

Research Design

Bibliometric is the measurement and analysis of scientific publications, authors and all kinds of written instruments (Broadus, 1987). Bibliometric methods have been used to perform quantitative analysis of scientific publications (Ellegaard & Wallin, 2015). In this study, a descriptive and descriptive approach was taken. In this study, the citation relationships, collaboration between authors, analysis of the use of keywords, and the relationships between the bibliographies of the studies were examined with bibliometric analysis method and bibliometric mapping technique of educational research on coding or programming published in WOS. The data to be downloaded from WOS were visualized with the bibliometric software tool VOSviewer to reveal the current situation descriptively and quantitatively. Trends related to coding, important studies and the relationship between studies were revealed.

Population and Sample of the Research

The universe is a complete and complete set that represents the entire subject to be studied, which is desired to be generalized. The sample can be defined as a subset representing the universe. Studies published on coding or programming constitute the population of the research. Educational research on coding listed in WOS until October 2023 constitutes the sample of the research.

Data Collection Tools

In this research, WOS, which is widely used worldwide, was preferred. The selected database should be compatible with the bibliometric software tool to be used. VOSviewer is

an important data visualization tool for bibliometric analysis. VOSviewer, which will be used for bibliometric analysis in this research, is compatible with the WOS database.

Data collection

Coding education and programming education were used interchangeably in studies on coding. In the "Computing Our Future" report published by European Schoolnet, it was mentioned that the concepts of coding and programming are used interchangeably (Balanskat & Engelhardt, 2014). For this reason, the research was not limited to the keyword "coding", but the keyword "programming" was also included in the search in order to cover a wide area.

In the research, the "Advanced Search" tab was clicked on the WOS database. Then, the search type was selected as “Topic”, and the keywords "coding" and "programming" were added to the query with the conjunction "OR" (or). The "search" button was clicked. In the menus on the left, the "Research Areas" tab was clicked, the “Education Educational Research” tab was selected, and the articles on coding or programming were limited to the field of educational research. As a result of the search, 20519 articles were found as of October 2023. The studies listed in WOS were downloaded as full record and cited references by clicking on the "Export" button and using the "tab delimited file" option. Since it could not be downloaded at once, it was downloaded in parts with five hundred studies.

Data Analysis

According to the content of the data, the VOSviewer program can present analyses such as co-citation analysis, co-authorship analysis, bibliographic coupling analysis, keyword analysis and citation analysis by visualizing them with bibliometric mapping method.

In this study, WOS was directly used for the productivity of scientific publications and the maps were interpreted by visualizing them with the bibliometric-mapping feature of the VOSviewer program for the analyses appropriate to the sub-problems. For the findings related to the research problem "What are the leading authors, institutions and countries/regions of educational research on coding listed in WOS?" bibliographic data in the WOS database were directly tabulated. For the other sub-problems, bibliographic data obtained from WOS were transferred to version 1.16.19 of the VOSviewer program and bibliometric maps were created with the analysis supported by the VOSviewer program.

FINDINGS

Analysis of Featured Authors, Institutions and Countries/Regions

Analysis of authors' number of studies

WOS database was used for the number of studies of the authors related to coding (programming). Some erroneous data were eliminated and the first 10 authors with the highest number of studies are given in table 3.1.

Table 1. Distribution of studies by authors

No	*Author Name*	*Number of Studies*
1	Bers, Marina Umaschi	46
2	Xinogalos, Stelios	43
3	Denny, Paul	35
4	Hellas Arto	34
5	Luxton-Reilly, Andrew	34
6	Leinonen, Juho	31
7	Becker, Brett A.	30
8	Kafai, Yasmin B.	29
9	Mozelius, Peter	29
10	Simon	29

This table lists the top 10 authors with the most published works.

When the distribution of the number of studies by authors is analyzed (table 3.1), Marina Umaschi Bers is the most prolific author with 46 studies. Marina Umaschi Bers is followed by Stelios Xinogalos (43 studies) and Paul Denny (35 studies).

Analysis of the number of studies of institutions

The distribution of studies according to institutions is given in two tables. These are the distribution of the studies according to the institutions (table 3.2) and the distribution of the studies according to the department to which the institutions are affiliated (table 3.3). When the distribution of studies according to institutions is analyzed (table 3.2), the University of California System ranks first with 424 studies, the Florida State University System ranks second with 354 studies, and the Ohio University System ranks third with 307 studies.

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Table 2. Distribution of studies by institutions

No	*Institutions*	*Number of Studies*
1	University of California System	424
2	State University System of Florida	354
3	University System of Ohio	307
4	University System of Georgia	300
5	University of North Carolina	274
6	Pennsylvania Commonwealth System of Higher Education Pcshe	262
7	Purdue University System	210
8	California State University System	194
9	University of Texas System	177
10	University of Toronto	174

This table lists the top 10 institutions with the most published work.

When the distribution of the studies according to the department to which the institutions are affiliated (Table 3.3) is examined, the Faculty of Education of Hong Kong University ranks first with 57 studies. The Faculty of Information Sciences at the University of Macedonia ranked second with 50 studies and the Faculty of Education at National Taiwan Normal University ranked third with 38 studies.

Table 3. Distribution of studies according to the departments of the institutions

No	*Departments of the Institutions*	*Number of Studies*
1	The University of Hong Kong Faculty of Education	57
2	University of Macedonia School of Information Sciences	50
3	National Taiwan Normal University College of Education	38
4	Arizona State University Ira A Fulton Schools of Engineering	35
5	University of Toronto Temerty Faculty of Medicine	32
6	University of Wisconsin Madison School of Education	31
7	Maastricht University Faculty of Health Medicine and Life Sciences	30
8	Stockholm University Department of Computer and Systems Sciences	28
9	University of California San Francisco School of Medicine	28
10	Beijing Normal University Faculty of Education	27

This table lists the departments of the top 10 institutions with the most published work.

Analysis of the number of studies by country/region

When the distribution of studies by countries/regions (Table 3.4) is analyzed, the United States of America ranks first with 7928 studies, the People's Republic of China ranks second with 1300 studies and Spain ranks third with 1103 studies.

Table 4. Distribution of studies by countries/regions

No	*Countries*	*Number of Studies*	*20519 Studies %*
1	USA	7928	38,63%
2	Peoples Republic of China	1300	6,33%
3	Spain	1103	5,37%
4	Canada	920	4,48%
5	England	832	4,05%
6	Australia	702	3,42%
7	Germany	590	2,87%
8	Türkiye	487	2,37%
9	Brazil	438	2,13%
10	Taiwan	420	2,04%

This table lists the top 10 countries with the most published studies.

Distribution of studies according to years of publication

When the graph of the distribution of studies according to publication years (Figure 3.1) is analyzed, it is seen that most studies were published in WOS in 2019.

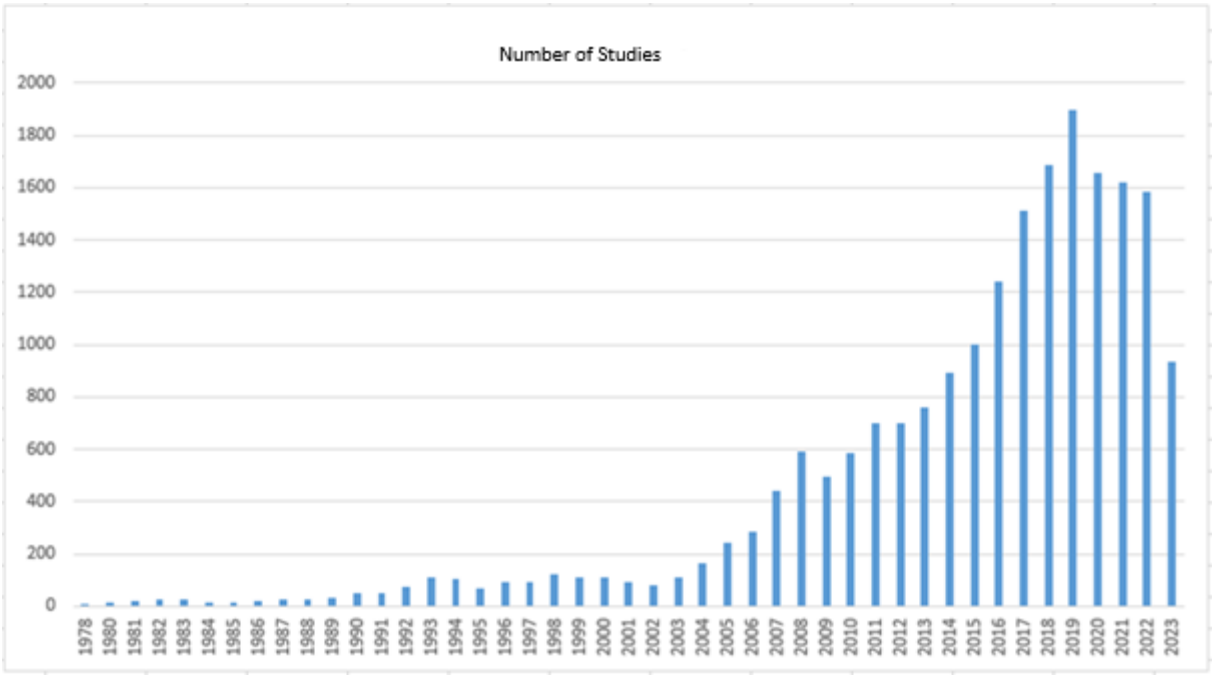

Fig. 1. Distribution of studies by publication years (1978 - October 2023)

When the distribution of the number of studies according to publication years (table 3.5) is examined, 2019 was the year in which the most studies were published in WOS with 1896 studies. When Figure 3.1 is analyzed, it is seen that there is a continuous increase in studies until 2019. In the following years, it is seen that the studies are around 1600, so it can be said that educational research on coding (programming) continues to maintain its importance.

Table 5. Distribution of the number of studies according to publication years

Year of Publication	*Number of Studies*	*Year of Publication*	*Number of Studies*
1978	2	**2002**	83
1980	12	**2003**	113
1981	20	**2004**	167
1982	29	**2005**	245
1983	27	**2006**	284
1984	16	**2007**	443
1985	15	**2008**	593
1986	22	**2009**	495
1987	28	**2010**	583
1988	27	**2011**	703
1989	35	**2012**	703
1990	52	**2013**	759
1991	53	**2014**	892
1992	76	**2015**	1001
1993	108	**2016**	1241
1994	105	**2017**	1510
1995	69	**2018**	1688

1996	91	**2019**	1896
1997	95	**2020**	1658
1998	125	**2021**	1620
1999	110	**2022**	1585
2000	109	**October-2023**	936
2001	95		

This table includes 20,519 studies listed on Web of Science related to educational research on coding. (1978-October 2023)

Citation Analysis

To understand citation analysis, it is necessary to know the concept of citation. A citation is when an author cites a work in his/her own bibliography if he/she includes information from another source in his/her own bibliography. If book A contains a bibliographic information introducing book B, book A contains a reference to book B. For book A, a citation was made to book B (Gökkurt, 1997).

Citation analysis has been widely used to identify collaboration between scientific publications, map the image of authors' research fields, assess the impact of research outputs, and observe knowledge transfer across fields (Ding et al., 2014). Citation analysis helps not only to measure the performance of authors, universities and journals but also to measure the scientific quality of studies (Civelek Uzun, 2022).

Citation analysis of documents

After the dataset was uploaded to the Vosviewer program, citation analysis of the studies was performed, all 20519 studies were included, the 10 studies with the highest link strength and their authors were listed and Table 3.6 was obtained.

Table 6. The 10 studies and their authors with the highest link strength

No	*Document Name*	*Author and Year of Publication*	*Citations*	*Link Strength*
1	Demystifying computational thinking	Shute (2017)	399	107
2	Computational thinking and tinkering: Exploration of an early childhood robotics curriculum	Bers (2014)	395	92
3	How to learn and how to teach computational thinking: Suggestions based on a review of the literature	Hsu (2018)	254	85
4	Introductory Programming: A Systematic Literature Review	Luxton-Reilly (2018)	148	80
5	Problem solving by 5-6 years old kindergarten children in a computer programming environment: A case study	Fessakis (2003)	202	75
6	Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts?	Denner (2012)	200	64
7	The Effects of Teaching Programming via Scratch on Problem Solving Skills: A Discussion from Learners' Perspective	Kalelioglu (2014)	142	60
8	Designing for deeper learning in a blended computer science course for middle school students	Grover (2015)	176	58
9	Computational thinking in compulsory education: Towards an agenda for research and practice	Voogt (2015)	207	58
10	The Effect of a Classroom-Based Intensive Robotics	Kazakoff	175	56

	and Programming Workshop on Sequencing Ability in Early Childhood	(2013)

This table presents the 10 studies with the highest link strength.

When Table 3.6 is examined, the study with the highest link strength and number of citations is "Demystifying computational thinking" by (Shute et al., 2017). The study titled "Computational thinking and tinkering: Exploration of an early childhood robotics curriculum" by (Bers et al., 2014) ranked second. "How to learn and how to teach computational thinking: Suggestions based on a review of the literature" by (Hsu et al., 2018) ranked third.

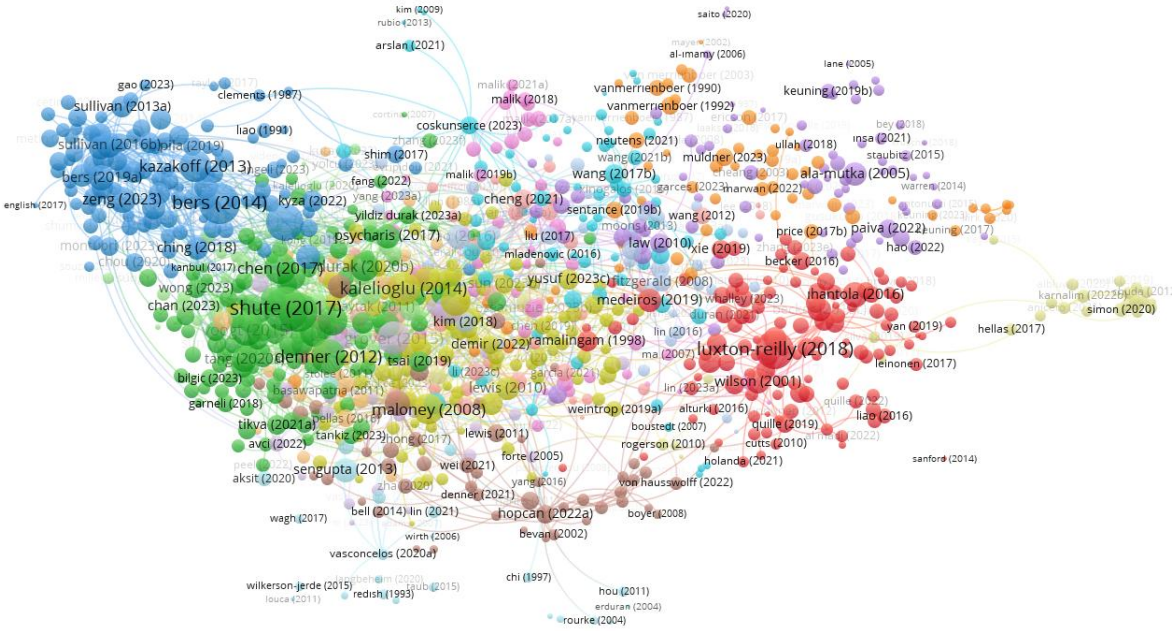

Fig. 2. Citation analysis of studies (link weighted)

The citation analysis of the studies was performed by transferring the data downloaded from WOS to the VOSviewer program. In the citation analysis of the studies (Figure 3.2), 984 studies with high link strength and number of citations out of 20519 studies were shown in 16 clusters and a map weighted by the number of links was created. The size of the circles is directly proportional to the number of links. The larger the circle, the more links. (van Eck & Waltman, 2010) state that mapping and clustering complement each other. While mapping provides a detailed picture of the structure of a bibliometric network, clustering provides a rough picture of the structure of a bibliometric network. In Figure 3.2, similar topics in the authors' works are grouped within the same color cluster. The closer the circles are to each other, the higher the similarity between the studies. The connections between the circles show the citation relationship between the studies. The thickness of the line between the circles indicates the strength of the relationship between the studies. When Figure 3.2 is examined, the studies of (Shute et al., 2017),(Luxton-Reilly et al., 2018), (Bers et al., 2014), and (Kalelioglu & Gülbahar, 2014) are highly cited and highly linked studies in different clusters of coding (programming).

Citation analysis of authors

The author's citation analysis map is presented in Figure 3.3. Scientific Mapping was created with total link strength (TLS) weighting. Out of 47403 authors, 279 authors with at least 7 studies and high citation count and TLS were mapped in 14 clusters.

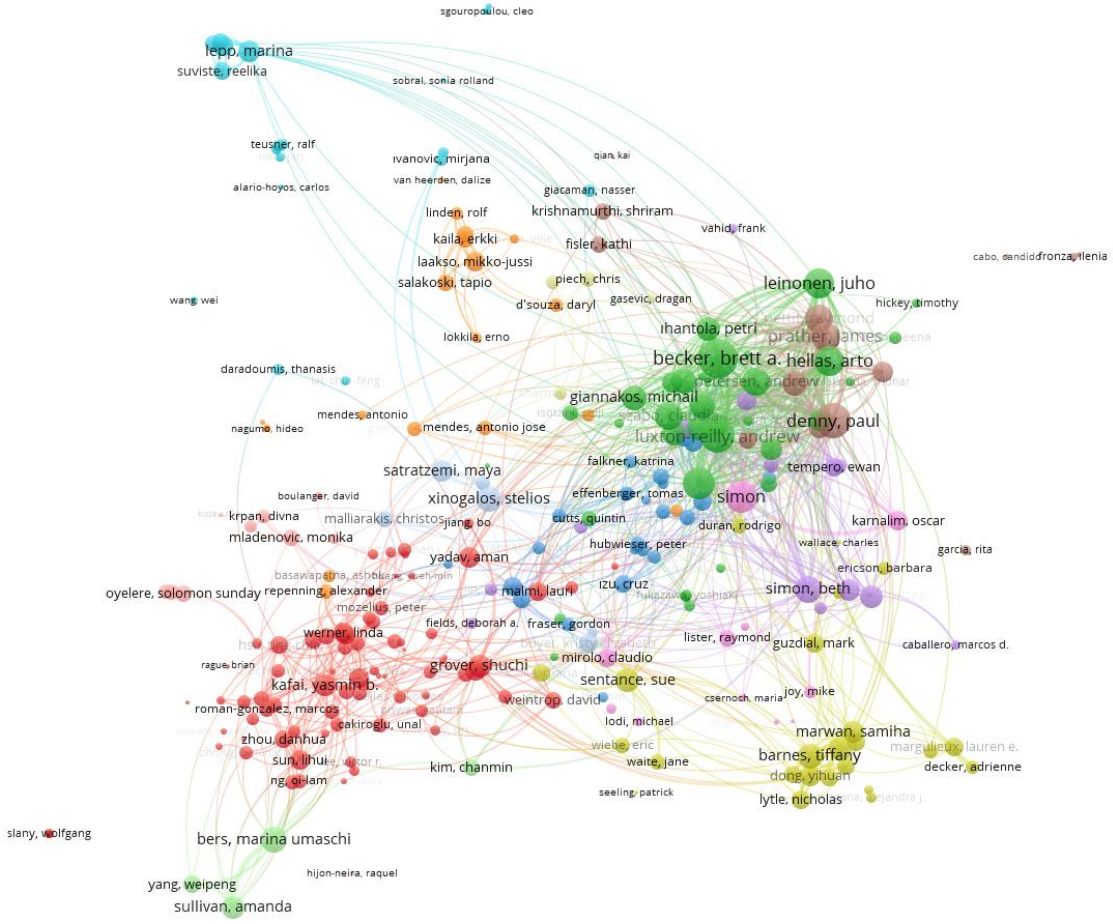

Fig. 3. Citation of authors analysis (TLS weighted)

When Figure 3.3 is analyzed, it can be said that Brett A. Becker, Paul Denny and Andrew Luxton-Reilly are the authors with the highest TLS in the citation analysis of the authors, respectively.

Citation analysis of the institutions to which the author is affiliated

The citation analysis map of the author's affiliated institution (Figure 3.4) is TLS-weighted. Out of 9246 institutions, 1000 institutions with high TLS with at least 5 studies are shown as a map.

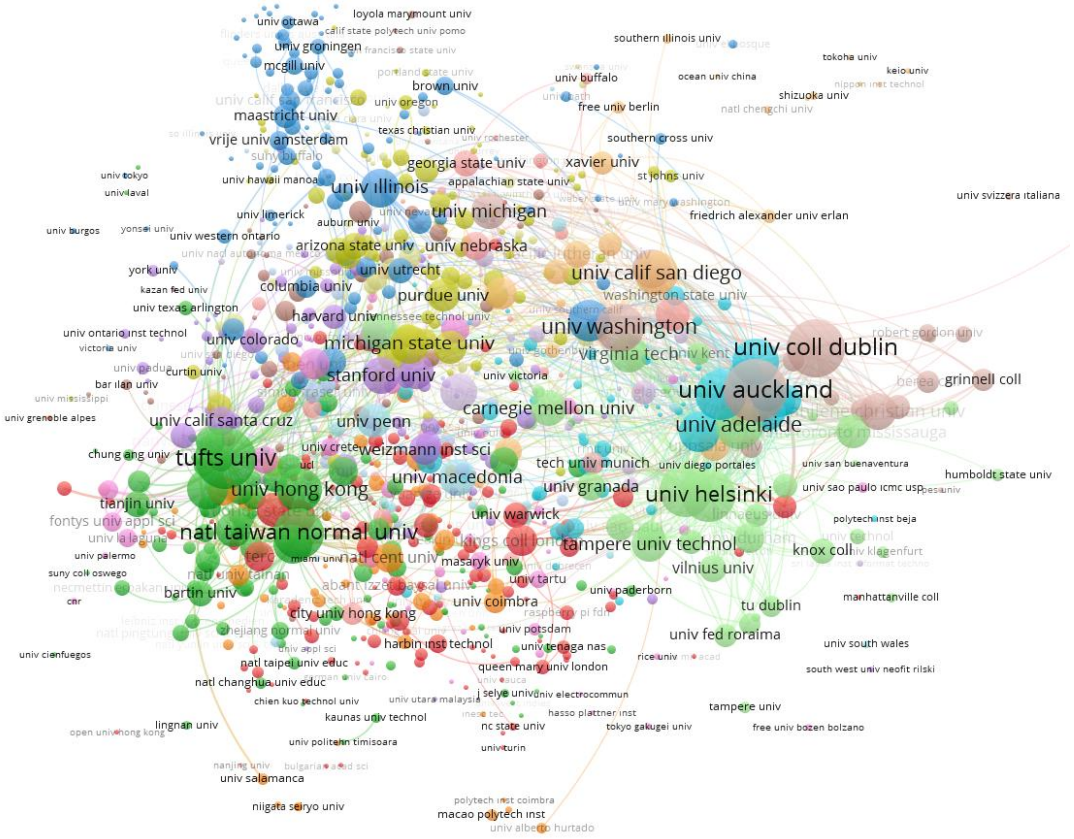

Fig. 4. Citation analysis of institutions to which the author is affiliated (TLS weighted)

When the citation analysis (TLS Weighted) map of the author's affiliated institution in Figure 3.4 is examined, it can be said that Tufts University has the highest number of citations and TLS. The circles of the University of Auckland, University College Dublin and the University of Helsinki are quite large. It is possible to say that these universities are the institutions with the highest citation relationship.

Citation analysis of countries to which the author is affiliated

In Figure 3.5, the citation analysis map of the countries/regions to which the author is affiliated is presented with TLS weighting. In Figure 3.7, 100 interconnected countries with at least five studies from 159 countries are mapped. The size of the circle is directly proportional to the TLS. The country with the highest number of citations and TLS is the USA. It is followed by China and the UK.

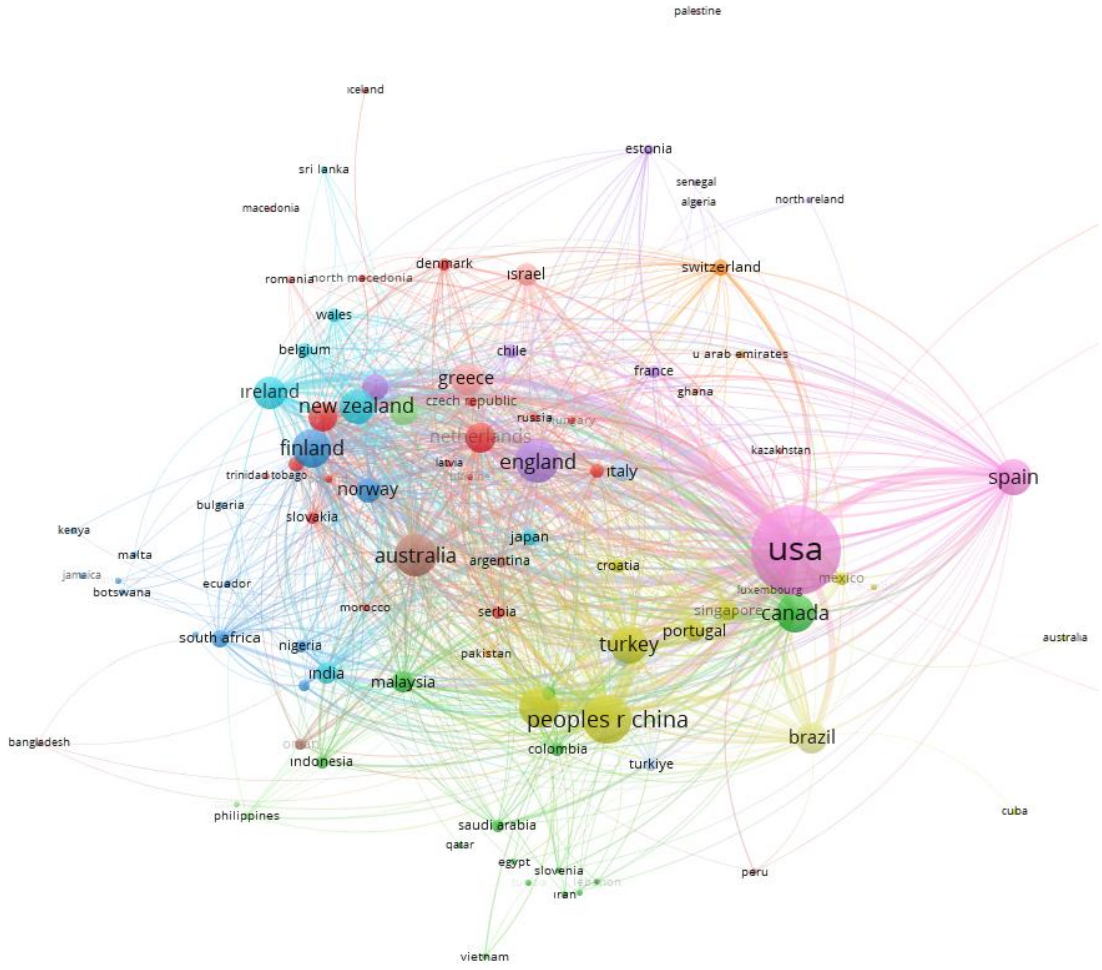

Fig. 5. Citation analysis of the countries/regions to which the author is affiliated (TLS weighted)

Co-authorship Analysis

Co-authorship analysis reveals the collaboration and interaction between authors working in a particular subject area. Collaboration between authors is considered positive in terms of enriching ideas (Barak, 2022). In studies conducted in the literature, co-authorship analysis mostly emphasizes understanding the patterns of collaboration between scientific studies, capturing collaborative statistics between authors, and identifying prominent authors on the topic of study (Uddin et al., 2012).

Co-authorship of authors analysis

In Figure 3.6, out of a total of 47403 authors, 752 authors with at least 5 studies, 313 authors who are connected to each other are mapped as 28 clusters. Each color on the map indicates a different cluster. These clusters list groups of authors working in the same or similar research areas. Closeness between two circles may indicate that they have co-authorship relationships. That is, it reflects the relationship or collaboration between authors of the same studies. The greater the closeness between authors, the greater the collaboration between them. The thickness of the lines indicates the strength or intensity of the relationship between two nodes or elements (for example, author or study). Thicker lines represent a stronger or tighter relationship, while thinner lines reflect a weaker or less tight relationship.

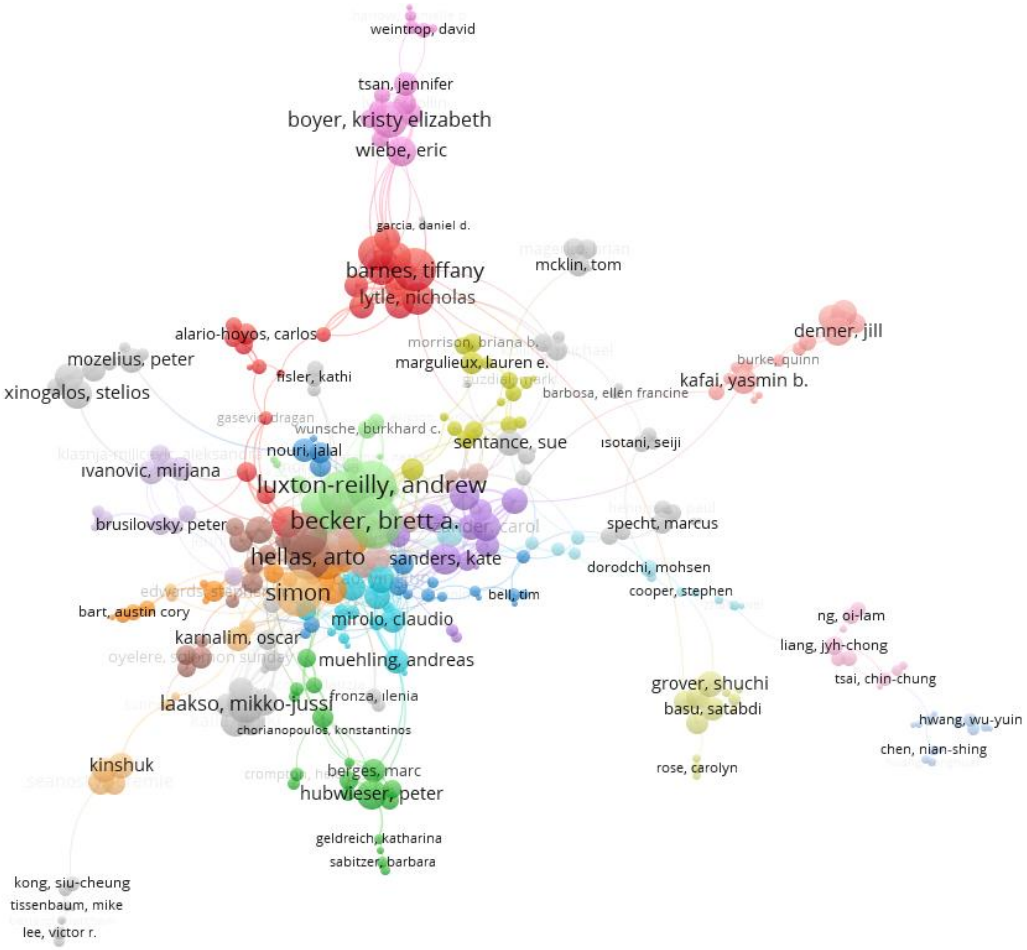

Fig. 6. Co-authorship of authors analysis (TLS weighted)

VOSviewer data and Figure 3.6 show that Brett A. Becker is the author with the highest TLS. It can be said that Brett A. Becker is the author with the highest co-authorship relationship. Brett A. Becker, Andrew Luxton-Reilly, Arto Hellas, Simon can be shown among the authors with high TLS. Figure 3.6 shows that authors are clustered in different colors. Authors who are close to each other can be said to have a co-authorship relationship.

Co-authorship analysis of the institutions to which the author is affiliated

In Figure 3.7, the co-authorship map of the institutions to which the authors are affiliated is TLS-weighted. In Figure 3.7, the 247 institutions with the highest TLS with at least 5 studies out of 9246 institutions are mapped into 8 different clusters.

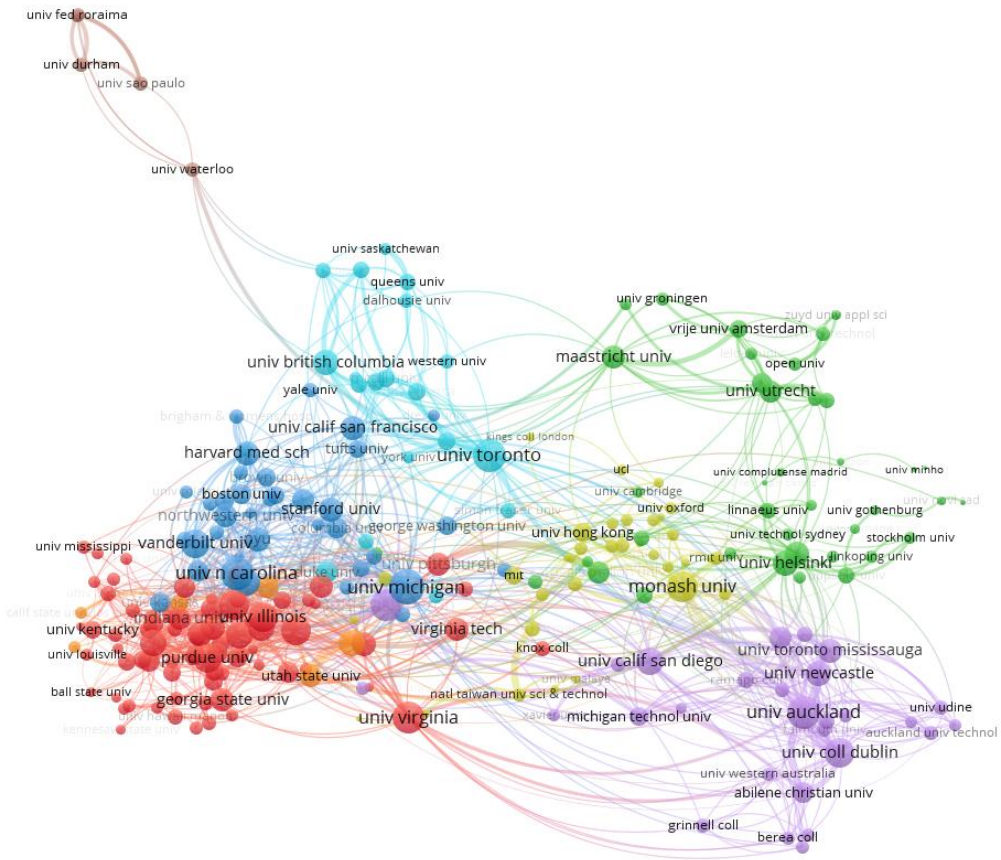

Fig. 7. Co-authorship analysis of the institutions to which the author is affiliated (TLS weighted)

When the map in Figure 3.7 is analyzed, it can be said that University of Michigan, University of Toronto and University of Auckland are the institutions with the highest TLS and co-authorship relationship. In Figure 3.7, it is possible to say that universities in the same color group work on similar themes. The links between them indicate co-authorship.

Co-authorship analysis of countries to which the author is affiliated

In Figure 3.8, according to VOSviewer data, 98 countries—each having at least five studies published in the journal and exhibiting high connectivity strength—are grouped into 10 clusters. When Figure 3.17 is analyzed, it can be said that the country with the highest TLS is the USA. It has connections with many countries as a co-author. After the USA, the UK and Australia come after the USA as countries with strong co-authorship relations.

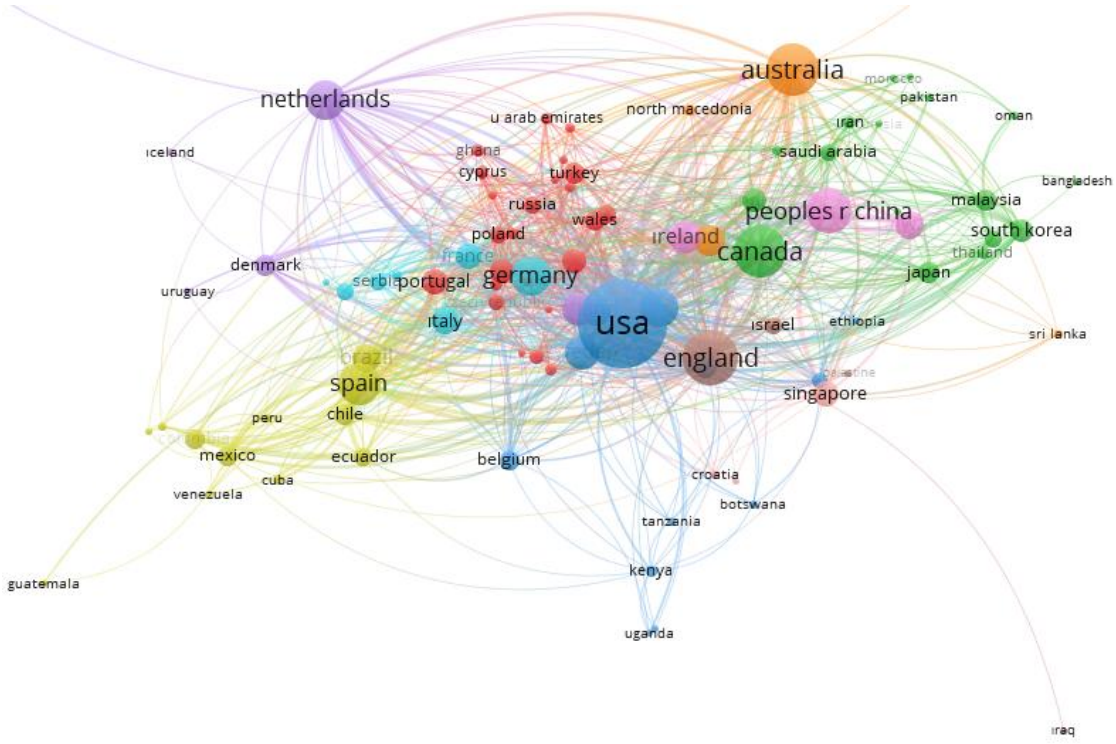

Fig. 8. Co-authorship analysis of countries/regions of author affiliation (TLS weighted)

Co-occurrence of Author Keywords Analysis

The co-occurrence of author keywords analysis analyzes the frequency with which terms occur together in texts. This analysis is used to determine the relationship of a particular topic or term with other terms. Cooccurrence of keywords analysis can be used to examine the conceptual structure of studies (Cobo et al., 2011). It can also identify similar topics and research trends.

The co-occurrence distribution of keywords in the studies is listed in Table 3.7. When Table 3.7 is examined, it is noteworthy that the keywords with the highest co-occurrence and connection strength are "programming", "computational thinking" and "education". The keyword "coding" ranks seventh. Here, it can be said that the keyword "programming" is found together more than the keyword "coding".

Table 7. Co-occurrence distribution of keywords

No	*Keywords*	*Co-occurance*	*Total Link Strength*
1	Programming	1304	2611
2	Computational Thinking	819	1587
3	Education	558	1103
4	Computer Science Education	474	888
5	CS1	308	619
6	Robotics	245	556
7	Coding	267	535
8	Computer Science	229	521
9	Scratch	231	498

10	Assessment	313	488
11	STEM (Science, technology, engineering and mathematics)	206	482
12	Learning	229	474
13	Computer Programming	292	468
14	Higher Education	331	442
15	Teaching	223	436
16	E-Learning	290	377
17	Motivation	195	368
18	Collaborative Learning	233	337
19	Curriculum	179	317
20	Problem Solving	152	314

This table includes the first 20 words with the highest TLS count.

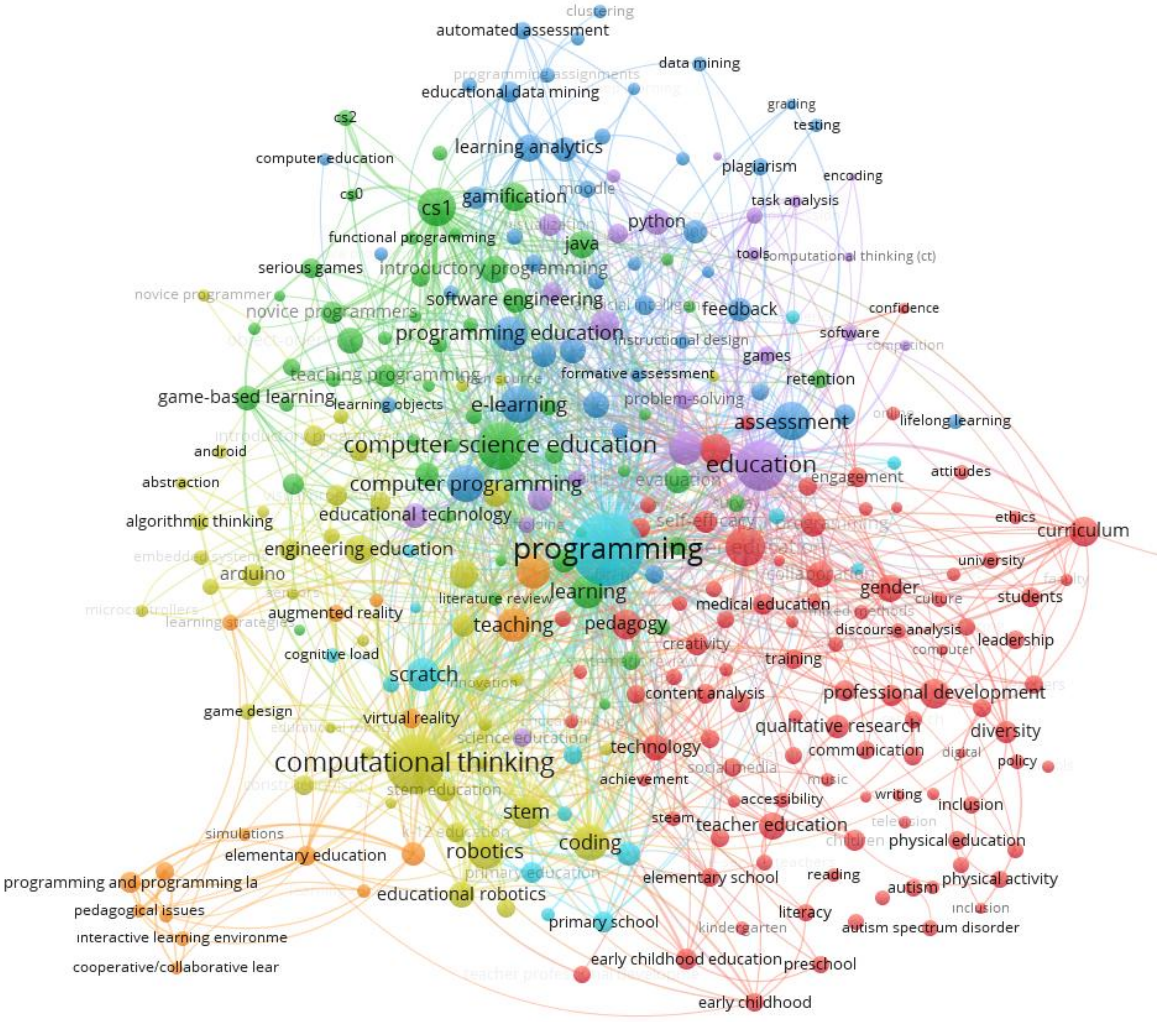

Fig. 9. Co-occurrence distribution of keywords according to clusters

Figure 3.9 shows the cooccurrence distribution of keywords according to clusters. In Figure 3.9, according to VOSviewer data, the 300 keywords with the highest TLS that are repeated at least 5 times out of 31505 keywords are shown in 8 different clusters in the form of scientific

mapping. When Figure 3.9 is examined, the keyword "programming" is located in the center of the map. The size of the circle in the keywords is directly proportional to the number of keywords that are repeated the most or found together. “Computational thinking”, “education” and “computer science education” respectively follow the keyword “programming”. It is noteworthy that keywords such as "computational thinking", "stem", "coding" and "robotics" etc. are in the same color cluster. It can be mentioned that these keywords are frequently used in similar themes.

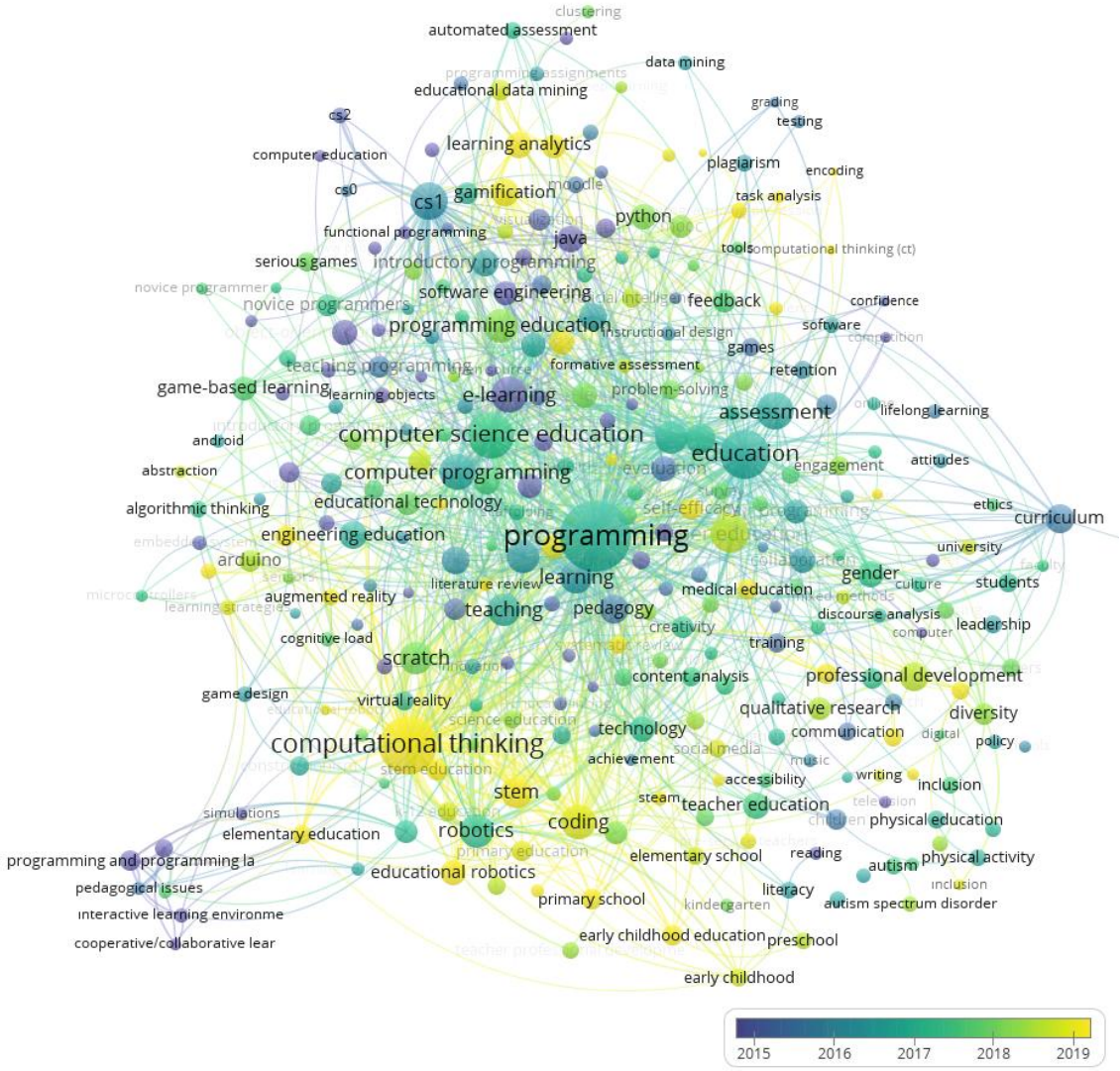

Fig. 10. Co-occurrence distribution of keywords by years

Figure 3.10 shows the co-occurrence distribution of keywords by year. When Figure 3.10 is examined, an indicator chart can be seen from purple to green and yellow between 2015-2019. When the map is examined, it can be said that keywords such as "e-learning", "java" and "software engineering" etc. are repeated more frequently in 2015 since they are in shades of purple. Likewise, keywords such as "programming", "robotics", "computer science education", "scratch" etc. are in shades of green, so it can be said that they were repeated more frequently between 2016-2018. In recent years, keywords such as "computational thinking", "coding" and "stem" etc. are repeated more frequently.

Bibliographic Coupling Analysis

The term bibliographic coupling was first used by (Kessler, 1963). Bibliographic coupling occurs when two separate studies cite a common third study. In other words, it can be said that one or more references are shared by two documents (Small, 1973). It can be said that bibliographic coupling is stronger as the increase in the number of common citations that authors have in their works. Bibliographic coupling is used to estimate how similar the subject matter of two works is. Bibliographic coupling can give an idea about the similarity of newly published works that have not been cited. It does not provide information about whether these studies are important or not (Yılmaz, 2021)). As the number of co-cited studies increases, the bibliographic coupling relationship increases in direct proportion. In bibliographic coupling analysis, the reference relationship is briefly examined. It can be said that bibliographic coupling analysis is a powerful tool to understand developments and trends in the literature.

Bibliographic coupling analysis of authors

The bibliographic coupling analysis of the authors is shown in Figure 3.11 with TLS weighted. The table in Figure 3.11 shows that Brett A. Becker, Andrew Luxton-Reilly, Simon and Marina Umaschi Bers are the authors with the highest TLS.

Verify selected authors

Selected	Author	Documents	Citations	Total link strength
☑	becker, brett a.	30	449	48418
☑	luxton-reilly, andrew	34	461	44270
☑	simon	29	349	40602
☑	bers, marina umaschi	37	1406	34467
☑	sheard, judy	11	405	33997
☑	kong, siu-cheung	19	336	30947
☑	szabo, claudia	9	338	29759
☑	hellas, arto	34	170	28197
☑	giannakos, michail	11	203	25740
☑	kumar, amruth n.	25	210	25384
☑	sun, lihui	10	93	25248
☑	denny, paul	35	319	25193
☑	ott, linda	7	180	23954
☑	wong, gary k. w.	14	101	21788
☑	leinonen, juho	30	116	21486
☑	roman-gonzalez, marcos	12	496	21291
☑	scott, michael james	8	185	21092
☑	weintrop, david	14	287	21083
☑	kafai, yasmin b.	22	686	21061
☑	robles, gregorio	13	284	20832

Fig. 11. Bibliographic coupling analysis of authors (TLS Weighted table)

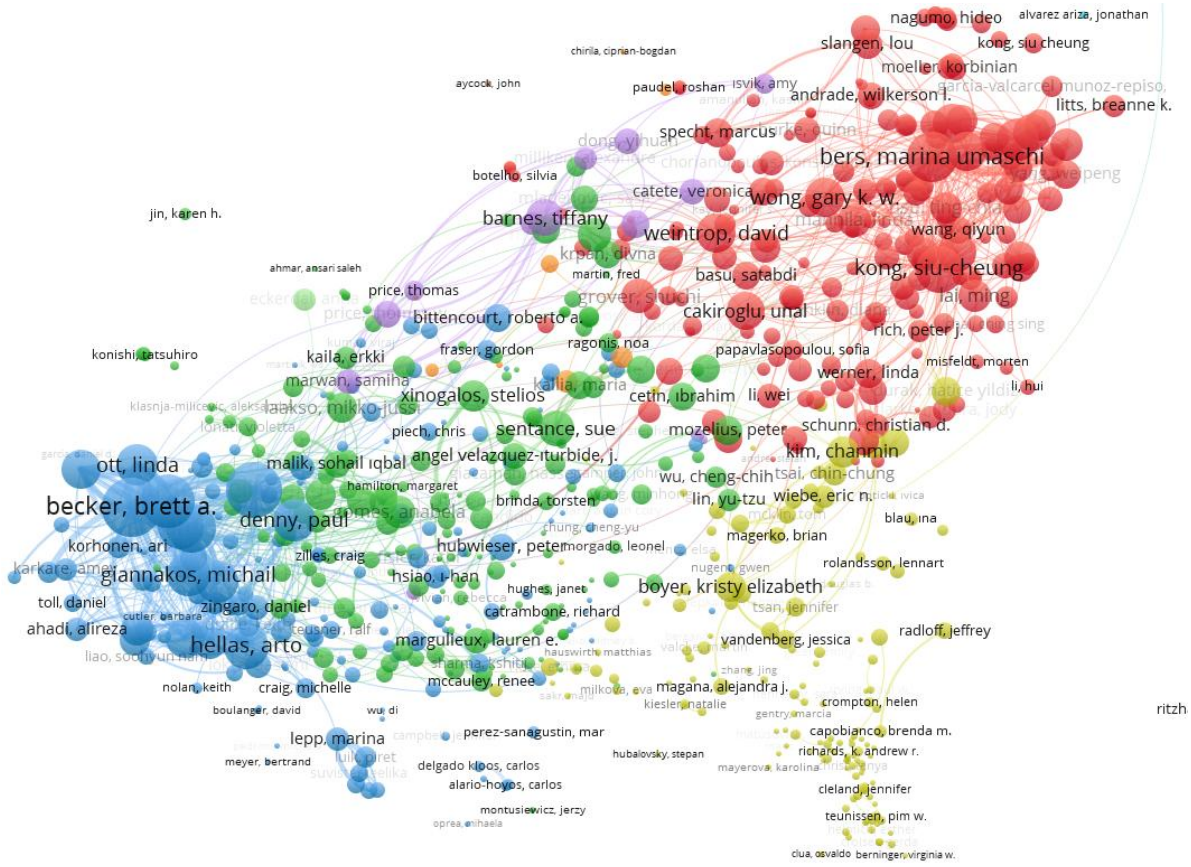

Fig. 12. Bibliographic coupling analysis of authors (TLS weighted)

Figure 3.12 shows the network map of bibliographic coupling of authors. Out of 47403 authors, 747 authors with high TLS who have at least 5 studies were mapped in 11 clusters. Figure 3.12 shows the relationships between authors citing the same source. Each color represents a different cluster. It is possible to say that authors such as Brett A. Becker, Marina Umaschi Bers, Kristy Elizabet Boyer and Tiffany Barnes etc. are high TLS authors working on different themes in different color clusters.

Bibliographic coupling analysis of documents

The bibliographic coupling analysis of the studies is given in Figure 3.13. In Figure 3.13, 1000 studies with high TLS out of 20519 studies are visualized in 4 clusters by scientific mapping method. Studies clustered in the same color can be mentioned in terms of the proximity of the circles to each other and the similarity relationship between the subjects according to the color clusters.

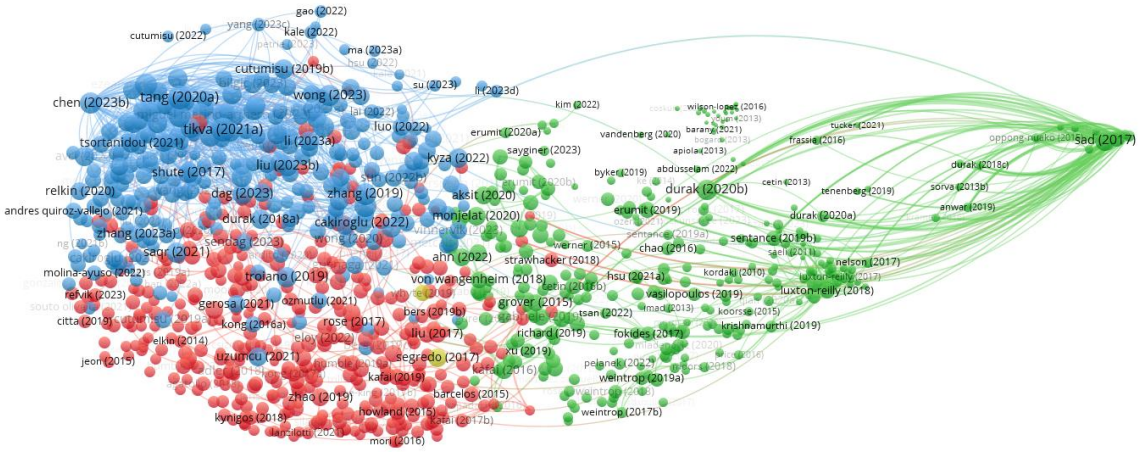

Fig. 13. Bibliographic coupling analysis of studies (TLS weighted)

Verify selected documents

Selected	Document	Citations	Total link strength
☑	tang (2020a)	207	4690
☑	tikva (2021a)	72	4678
☑	ezeamuzie (2022a)	22	4089
☑	zhang (2019)	166	3846
☑	othman (2023)	0	3830
☑	miguel merino-armero (2022)	13	3818
☑	wong (2023)	0	3683
☑	yildiz durak (2023a)	5	3678
☑	ısrael-fishelson (2022)	20	3673
☑	chen (2023b)	4	3595
☑	liu (2023b)	0	3518
☑	tikva (2021b)	7	3458
☑	cakiroglu (2022)	1	3406
☑	saqr (2021)	18	3389
☑	dag (2023)	0	3384
☑	troiano (2019)	15	3382
☑	durak (2020b)	52	3353
☑	sun (2022c)	10	3342
☑	relkin (2021b)	48	3334
☑	shute (2017)	399	3323

Fig. 14. Bibliographic coupling analysis of studies (TLS weighted table)

When Figure 3.13 and Figure 3.14 are examined, the study with the highest bibliographic coupling relationship is "Assessing computational thinking: A systematic review of empirical studies" by (Tang et al., 2020). (Tikva & Tambouris, 2021)'s "Mapping computational thinking through programming in K-12 education: A conceptual model based on a systematic literature review" ranks second. (Ezeamuzie & Leung, 2022)'s "Computational Thinking Through an Empirical Lens: A Systematic Review of Literature" ranked third. The study titled "Mapping Computational Thinking Skills Through Digital Games Co-Creation Activity Amongst Malaysian Sub-urban Children" by (Othman et al., 2023) did not receive any citations despite its high TLS. Bibliographic coupling analyses are evaluated independently of the number of citations and do not provide information about its importance. It can be said

that bibliographic coupling studies have more bibliographical relationships. When the studies with high TLS are examined, it is noteworthy that there are systematic literature reviews.

Bibliographic coupling analysis of the institutions to which the author is affiliated

Figure 3.15 shows the bibliographic matching analysis of the institutions to which the authors are affiliated. Out of 9246 institutions, 1000 institutions with high TLS with at least 5 studies were visualized in 6 clusters with the scientific mapping method.

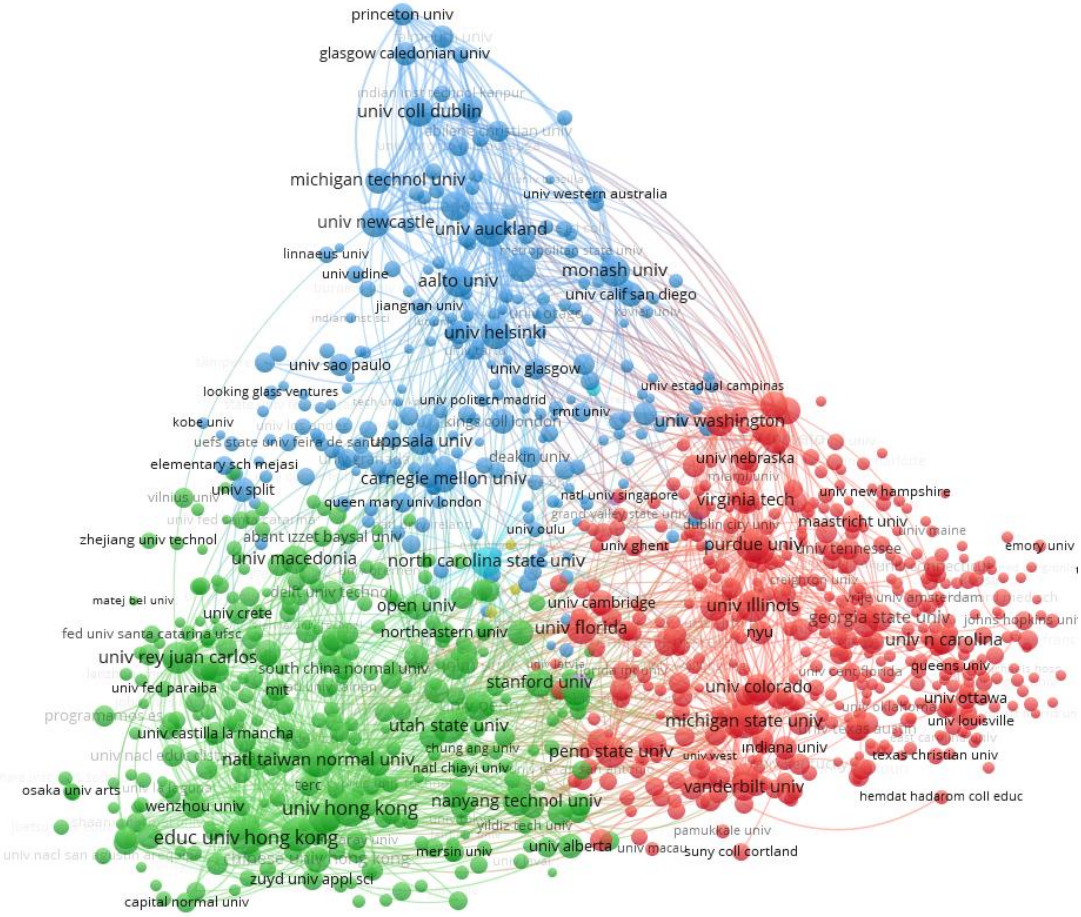

Fig. 15. Bibliographic coupling analysis of the institutions to which the author is affiliated

Figure 3.15 shows that the three institutions with the highest bibliographic matching relationship are the University of Hong Kong, Purdue University and National Taiwan Normal University. In Figure 3.15, each color cluster represents a different theme. It can be said that the University of Hong Kong in the green color cluster, Purdue University in the red color cluster, University of Auckland in the blue color cluster and North Carolina State University in the light blue color cluster are universities with high bibliographic matching relationships in different themes.

Bibliographic coupling analysis of countries to which the author is affiliated

Figure 3.16 shows the bibliographic matching analysis of the countries/regions to which the authors are affiliated. 101 countries with high TLS scores, out of 159 countries, with the 5 most published studies, were visualized in 6 clusters using the scientific mapping method.

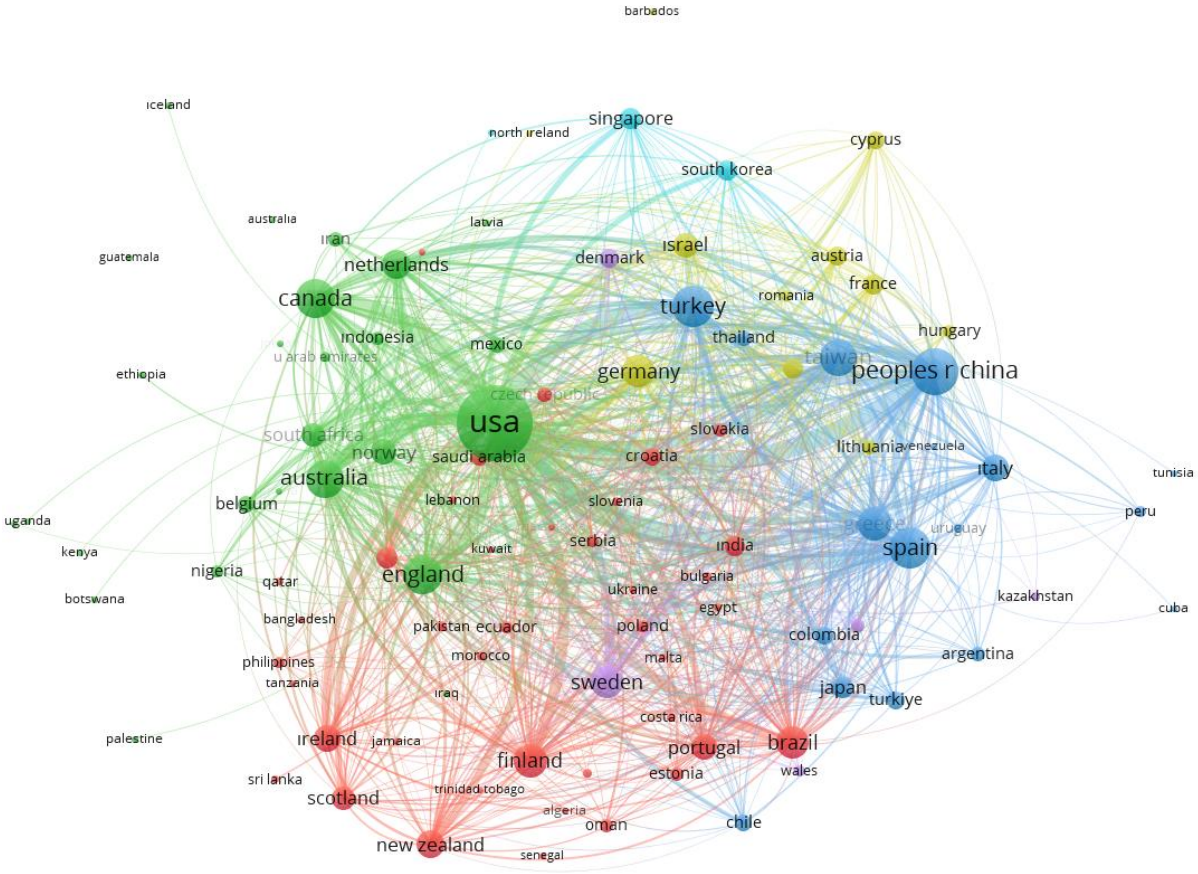

Fig. 16. Bibliographic coupling analysis of countries/regions

When Figure 3.16 is analyzed, it can be said that the countries with a high bibliographic matching relationship are the USA, the People's Republic of China, Spain and Turkey, respectively. Countries such as USA, UK, Australia, Canada, Netherlands etc. are in the green color cluster. Countries such as People's Republic of China, Spain, Italy, Turkey etc. are in the blue color cluster. Countries such as Finland, Brazil, New Zealand, Ireland etc. are in the red color cluster and countries such as Germany, France, Austria etc. are in the yellow color cluster. Each color cluster represents different themes, and the size of the circle indicates that the bibliographic matching relationship is high. These countries in the same color cluster are countries with a high bibliographic matching relationship working on similar themes.

Discussion, Conclusion and Recommendations

This study conducted a comprehensive bibliometric analysis of 20,519 articles related to coding. It is seen that there is a limited number of systematic review, content analysis and meta-analysis studies on educational research in the field of coding in the literature. Existing studies generally focus on narrow topics and specific regions. Compared to the existing literature, both the temporal scope and the conceptual framework covered in this study are broader, so that the evolution of the concept of coding over time can be traced more clearly. Moreover, unlike previous studies, this analysis is not limited to specific geographical regions but offers a holistic perspective on a global scale. In this respect, the study provides an opportunity to evaluate developments in the field of coding from a broader and long-term perspective.

As a result of the analysis, the most productive author was Marina Umaschi Bers with 46

studies. The most productive institution was the University of California System with 424 studies. When the studies were analyzed according to the department to which the institutions were affiliated, the Faculty of Education of the University of Hong Kong was the most productive department with 57 studies. The most productive country was the United States of America with 7928 studies. It shows that the United State plays a central role in educational research on coding. By considering countries and institutions that are productive in the field of coding, successful practices can be transferred. According to the distribution of studies by years, it was seen that most studies were published in 2019 with 1896 studies.

The study with the highest citation relationship was "Demystifying computational thinking" by Shute et al. (2017). The author with the highest citation relationship is Brett A. Becker. It can be said that the university with the highest citation relationship is Tufts University. The country with the highest citation relationship and the most cited country is the USA. It is possible to say that the USA is an important country in coding (programming).

The author with the highest co-authorship relationship is Brett A. Becker. The institution with the highest co-authorship relationship is the University of Michigan. It can be said that the country with the highest co-authorship relationship is the USA.

According to the result of the co-occurrence analysis of keywords, it was seen that the keywords "programming", "computational thinking" and "education" were most frequently used together. When the keywords are grouped by years, it is seen that keywords such as "e-learning", "java" and "software engineering" etc. are repeated more frequently in 2015. Likewise, it can be said that keywords such as "programming", "robotics", "computer science education", "scratch" etc. were repeated more frequently between 2016-2018. In recent years, keywords such as "computational thinking", "coding" and "stem" were repeated more frequently. According to the analysis, it can be said that the keyword "programming" was used more frequently in previous years, while the keyword "coding" was used more frequently in recent years. Educational contents and curricula related to coding can be restructured in line with the trends in the literature. Especially the integration of subjects such as robotics, computational thinking, block-based programming and STEM, which have become prominent in recent years, into the curriculum will contribute to the provision of a qualified coding education in accordance with the needs of the age.

It can be said that the author with the highest bibliographic matching relationship is Brett A. Becker. The study with the highest bibliographic matching relationship is "Assessing computational thinking: A systematic review of empirical studies" by (Tang et al., 2020). It is noteworthy that the studies with the highest bibliographic matching relationship are systematic literature studies. The institution with the highest bibliographic matching relationship is the University of Hong Kong. It can be said that the country with the highest bibliographic matching relationship is the USA.

This study examined the current state of educational research on coding and showed the contributions of authors, institutions and countries to the literature. It provides an insight into the most frequently used keywords in the current literature in the field. It serves as a valuable reference for researchers and educational practitioners who want to understand or shape the future of coding in education. An accurate reading of the trends in the field will contribute to shaping future educational policies and research directions in a healthier way.

Apart from this study, bibliometric analysis of coding studies on the basis of countries can be

carried out. Apart from the Web of Science database, bibliometric analysis of the studies in Scopus, Dimensions, Lens and PubMed databases supported by VOSviewer can be performed. Furthermore, secondary analyses supported by qualitative and quantitative methods, such as in-depth content analysis or meta-analysis, would allow for a more detailed examination of pedagogical approaches to coding. In addition to bibliometric data, holistic studies analyzing variables such as student achievement, teacher efficacy and learning motivation are also recommended. Studies can be conducted on the topics researched by considering the keywords "computational thinking", "coding" and "stem", which have been frequently used in recent years related to the current subject area. The current findings can serve as a source for new studies.

Declarations

Conflicts of Interest: *There are no conflicts of interest in this article.*
Funding: *The authors have not received any financial support for this article.*
Data availability:*The author confirms that all data generated or analyzed during this study are included in this published article. Furthermore, primary and secondary sources and data supporting the findings of this study were all publicly available at the time of submission.*

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