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A large-scale study based on topic modeling to determine the research interests and trends on computational thinking

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Abstract

Computational thinking (CT) has started to attract attention as an important research topic in recent years. It is important to describe the CT field in detail and to determine the research interests and trends of studies in this field. In this most comprehensive and first topic modeling based study in the field of CT, it was aimed to determine the current situation and research interests and trends in the articles on CT from past to present. For this aim, articles containing the term "computational thinking" in the title, keywords and abstract were retrieved by a search on January 18, 2022 from Scopus database. As a result of the search, a total of 1083 articles related to CT published in the Scopus database as of the end of 2021 were obtained. The bibliometric analysis findings of the study showed that there has been a significant increase in the number of publications in this field, especially since 2015. Studies are mostly of United States origin. Although the studies are interdisciplinary, they have been published mainly in journals in the field of educational technologies. The topic modeling analysis showed that the articles in this field were grouped under 13 topics. The first three of these topics, in order of volume, are "Game based learning", "Programming skills" and "Early child coding", respectively. When the acceleration of the topics is examined, the first three, whose weight increased over time compared to other topics, came to the fore as "Programming skills", "Early child coding" and "robotic programming", respectively. As a result, it is expected that this study will guide future studies in terms of determining research interests and trends in the field of CT.

Keywords Computational thinking · Topic modeling · Data science applications in education · Research themes and trends

Extended author information available on the last page of the article

1 Introduction

One of the topics that today's education systems focus on is Computational Thinking (CT). In recent years, around the world, there has been a growing interest in CT education in K-12 schools and its role in acquiring children's thinking skills and digital competences (Angeli & Giannakos, 2020). CT can also be regarded as a combination of thinking skills that today's individuals need to have (Wing, 2006). CT is the process of dealing with a problem systematically and creating a solution. In this context, it is thought that CT has a great correlation in the acquisition of 21st century skills (Çoban & Korkmaz, 2021; Zhang & Nouri, 2019).

CT is a concept that emerged in the 1980s with attempts to introduce programming to young students (Papert, 1980). Later in 2006, Wing (2006) defines CT as a process that includes problem solving, system design and understanding human behavior by making benefit of the basic concepts of computer science (Wing, 2006). This definition highlight the emphasis on CT that it represents a universally applicable attitude and skill that everyone, not just computer scientists, will be willing to learn and use (Tekdal, 2021). This approach has led to a significant change in the consideration of CT (Angeli & Giannakos, 2020; Tekdal, 2021).CT can be thought of as the process of dealing with a problem systematically and creating a solution (Çoban & Korkmaz, 2021; Yang et al., 2016). In accordance with this, CT consists of a set of skills based on problem-solving skills (Ezeamuzie & Leung, 2021; Wing, 2006). In other words, CT helps people understand computable problems and choose the right tools and methods to solve problems (Angeli & Giannakos, 2020). Emphasizing one step beyond this (Wing, 2008), he stated that CT is not only the center of problem solving, but also improves and defines problems. In this context, CT is now indispensable not only for students in computer science-related departments, but also for students in other fields (Wing, 2008). Educators should create and promote facilities for learning CT (Hsu et al., 2018).

With the emphasis of CT in the field of educational research (Wing, 2006) studies related to this concept have been prominent since 2006 (Lyon & Magana, 2020). However, since 2010s, it has been observed that these studies have been especially on K-12 education (Ilic et al., 2018). In recent years, there has been a growing interest in CT Education and its role in children's acquisition of thinking skills and digital competences in K-12 schools around the world (Angeli & Giannakos, 2020; Balanskat & Engelhardt, 2014; Heintz et al., 2016; Passey, 2017).The literature on CT has shown that CT is one of the main topics of national education in many countries today (Hsu et al., 2018; Zhang & Nouri, 2019). At this point, CT is no longer just an independent discipline or an independent teaching field, but is also seen as applicable to different disciplines or daily life (Hsu et al., 2018; Tekdal, 2021). In other words, CT is widely associated with programming (Voogt et al., 2015), but programming is not the only approach studied in the literature (Tikva & Tambouris, 2021). As a matter of fact, CT has been widely used in different fields from mathematics to programming, from computer science to biology (Benakli et al., 2017; Bers et al., 2014; Dodig-Crnkovic, 2011; Evia et al., 2015; Grover et al., 2015; Mladenović et al., 2018; Rubinstein & Chor, 2014). There are studies in the CT literature which use development of operational thinking both in computer programming, and in such disciplines as mathemat-

ics and biology to train students' logical concepts, CT, problem solving skills, and deductive ability (Hsu et al., 2018). It can be said that CT skills can be developed not only for middle school and high school students, but also for kindergarten students. Therefore, educators and academics should be aware of the importance of IT for the future (Hsu et al., 2018; Tekdal, 2021).

1.1 Review of the literature

Especially since the 2000s, CT has continued to increase its popularity in many research areas, particularly in education, computers, engineering and social sciences (Hsu et al., 2018; Tekdal, 2021). The increase in the number of studies in the field of CT has also led to studies that provide a holistic view of the field and describe the field. Thus, a number of bibliometric, content anaylsis or systematic review studies have also been conducted to identify trends in this field. In fact, we have found a few systematic reviews, content analysis or bibliometric analysis studies about how to teach and learn CT (Hsu et al., 2018), learning CT with Scratch in K-9 (Zhang & Nouri, 2019), assessing computational thinking (Da Alves et al., 2019; Tang et al., 2020), CT through programming in education (Fagerlund et al., 2021; Tikva & Tambouris, 2021), examination of CT definition models (Ezeamuzie & Leung, 2021; Kalelioglu et al., 2016), CT in higher education (Lyon & Magana, 2020), general description of the field (Ilic et al., 2018; Tekdal, 2021).

Ilic et al., (2018) aimed to review the studies on CT indexed in Web of Science (WOS) and ERIC databases. In the study, 96 articles on CT published between 2006 and 2016 were subjected to quantitative content analysis. The results of the study showed that there has been an increase in the number of CT studies in recent years and they are predominantly in the field of computer science. In addition, CT studies have been published in journals in the field of Education and Instructional Technologies. The sample of CT studies was generally pre-university students, and written data collection tools and quantitative analyzes were preferred in the studies. Finally, it was seen that the findings mainly focused on CT skills. In the study of Hsu et al., (2018), with 120 articles published between 2006 and 2017, a meta-review was conducted to analyze the applied courses of CT education, the learning strategies adopted, the participants, the teaching tools, the programming languages and the course categories. The results of the study showed that CT in education has made great progress in the last decade, and research topics and teaching tools have become more diverse in recent years. In addition, it has been determined that CT is mainly applied to program design and computer science activities, while some studies are related to other topics. Zhang & Nouri (2019) conducted a systematic review presenting a synthesis of 55 experimental studies providing evidence for the development of CT through programming in Scratch at the K-9 level published between 2007 and 2017 years. Findings from the study revealed that students in K-9 can learn CT skills related to the basic concepts of programming through Scratch, taking into account the progress of learning. The results of the study revealed a variety of CT skills, including input/output, reading, interpreting and transmitting code, using multimodal media, predictive thinking, and human-computer interaction, in addition to basic programming skills. Da Alves et al., (2019) conducted a systematic mapping study to examine approaches to assessing

CT competencies based on code analysis in K-12 education. The results of the study revealed 14 approaches that focused on the analysis of code generated by students inferring CT competencies related to algorithms and programming. In another similar study, Tang et al., (2020) examined 96 journal articles to analyze specific CT assessments from four perspectives: educational context, assessment construct, assessment type, and evidence of reliability and validity. The results of study revealed that more CT assessments are needed, most CT assessments focus on students' programming or computational skills, traditional tests and performance assessments are often used to assess CT skills, and that more future evidence of reliability and validity should be collected and reported. Lyon & Magana (2020) has conducted a systematic review of 13 empirical articles investigating CT in teaching and learning contexts in higher education. The results of the study show that CT research in higher education is growing, but there are opportunities for further research. Tikva & Tambouris (2021) have proposed a conceptual model based on systematic review to map CT through programming in K-12 education field. In this study, which was carried out with 101 studies, a model consisting of 6 CT fields (i.e. Knowledge Base, Learning Strategies, Assessment, Tools, Factors and Capacity Building) and their interrelationships. In another similar study, Fagerlund et al., (2021) conducted a literature review on studies using Scratch in K–9 and researches what kind of CT is assessed in Scratch at the primary level. The results of the study revealed that the summarized "CT-enhancing" programming contents and activities in Scratch are very broad and multidimensional. Ezeamuzie & Leung (2021) conducted a systematic review of 81 empirical studies to examine the nature, clarity, and definitional patterns of CT. The results of the study showed that most of the reviewed studies operationalized CT thinking as a combination of programming concepts and preferred definitions from evaluative frameworks. Tekdal (2021) revealed the change of research trends in the field of CT in the last twelve years (2008–2020) with the bibliometric mapping analysis method. The descriptive mapping of the field was revealed with the study in which 321 journal articles obtained from the SCOPUS database were examined. In addition, according to the results of the study, research topics that contributed to the CT literature were grouped under three themes. These are integration of CT into Science, Technology, Engineering and Mathematics (STEM) education, experimental studies on the assessment of CT skills, and discussion of the definition of CT and CT skills. Finally, the highlighted aspect of CT is that this field has the general nature of an emerging discipline that is still immature and will continue to evolve in the future. Considering the sample numbers of the studies, it is seen that the most comprehensive study in this field is the bibliometric analysis study of Tekdal (2021) with 321 journal articles.

1.2 Importance of the study and the problem statement

As it can be understood from the literature review, CT has been attracting attention as a research topic in many fields, especially in education, computers, engineering and social sciences since the last ten years. (Tekdal, 2021; Zhang & Nouri, 2019). Besides that, as CT offers new research opportunities (Lyon & Magana, 2020) and is still evolving (Tekdal, 2021), a research paper to identify current research interests, trends and developments in the field of CT will be timely and critical to present the current

situation and shed light on future researchers. Various studies examining research in the field of CT can be mentioned in the literature. Of course, the contributions of each such study on CT to the field cannot be ignored. However, there are some limitations of such studies. Systematic review studies are generally carried out with a limited number of specific studies (Gurcan, Ozyurt, et al., 2021b). Besides, due to the fact that bibliometric analysis studies focus on certain indicators, there is a risk of missing some details (Gurcan, Ozyurt, et al., 2021). In addition, the fact that systematic review and content analysis studies are carried out with few documents and manually (Gurcan, Ozyurt, et al., (Gurcan et al. 2021b) ; Yang et al., 2016) creates difficulties for such studies in terms of large data sets (Gurcan, Ozyurt, et al., 2021b). In this context, topic modeling studies based on data/text mining have been preferred in recent years to eliminate such risks and for more in-depth and semantic analysis (Gurcan, Ozyurt, et al., (Gurcan et al. 2021b) ; Hu et al., 2014; Kang et al., 2019). In other words, topic modeling studies are seen as ideal studies to reveal the themes and trends of studies in any field in a comprehensive framework (Gurcan, Ozyurt, et al., 2021b). In this direction, topic modeling analysis take bibliometric analysis and systematic review studies one step further and make it possible to make semantic analyzes for the extraction of tacit information from big text sets. (Gurcan, Ozyurt, et al., (Gurcan et al. 2021b) ; Kang et al., 2019). The lack of topic modeling analysis for the description of the CT field in the literature makes this study necessary and important. With this study, besides the descriptive characteristics of the field, with semantic analysis, reseach interests and trends of the field will be revealed. In this context, the present study aimed to reveal the current status of the articles in the field of CT from the past to the present, as well as research interests and trends. This study, with a total of 1083 articles, is the most comprehensive study describing the CT field. This study is important in terms of being the most comprehensive study in the field of CT and the first study based on topic modeling. On the other hand, in the most comprehensive study in this field in the current literature (Tekdal, 2021), it was stated that the term CT was only searched in the title as the limitation, and it was also stated that it could be searched in the abstract in future studies. The present study meets this in its current form. In this context, it will look at the field from a broad perspective, describe all studies in detail, and reveal research interests and trends. Therefore, the current study analyzes the scientific literature on CT using article indexed in the Scopus database from the past to the end of 2021. Accordingly, the following research questions (RQs) were investigated in the study:

RQ1: What is the distribution of CT articles by years?
RQ2: Which are the prominent authors, countries and universities in CT articles?
RQ3: Which subject areas and journals stand out in CT articles?
RQ4: What are the prominent topics in CT articles?
RQ5: What are the trend topics in CT articles?

2 Method

2.1 Design of the study

The study is based on descriptive content analysis and topic modeling analysis. Descriptive content analysis involves organizing, categorizing, and comparing texts and thus obtaining results from texts (Cohen et al., 2017). Topic modeling analysis, on the other hand, has been frequently used in recent years to obtain automatic information and hidden semantic patterns from large texts (Gurcan, Ozyurt, et al., 2021b). Topic modeling is a probabilistic method for fishing out hidden semantic patterns from large sets of texts that are difficult to dealt with manually (Blei et al., 2003). In the topic modeling approach, textual documents contain hidden semantic patterns called "topics" and each of these topics is defined by a probability distribution over a fixed set of words (Blei et al., 2003; De Mauro et al., 2018). Latent Dirichlet Allocation (LDA) algorithm (Blei et al., 2003) which is a generative approach for probabilistic topic models, was used in the study. LDA is widely used in natural language processing, information retrieval, job postings, literature research, and content analysis based on topic modeling (De Mauro et al., 2018; Gurcan, Ozyurt, et al., (Gurcan et al. 2021b) ; Gurcan & Cagiltay 2020). In this context, LDA analysis was used in the study.

2.2 Search strategy and study selection

Scopus was chosen to reach as many articles as possible from the database. The Scopus database has been used to retrieve articles relevant to the scope of the study, as it covers more than 5000 publishers worldwide, including Elsevier, Emerald, IEEE, Sage, Springer, Taylor &Francis, and Wiley Blackwell and this number is increasing day by day (Evia et al., 2015; Gurcan, Cagiltay, et al., (Gurcan et al. 2021a) ; Mongeon & Paul-Hus 2016; Yung & Khoo-Lattimore, 2019). In order to include the most articles on Scopus, the term "computational thinking" was searched in the title, abstract and keywords and only journal articles (research and review) were selected. Finally, the year 2022 was excluded in the search and all journal articles from the past to the present (up to 2021) were selected. Based on these criteria, the following query was created:

> TITLE-ABS-KEY ("computational thinking") AND (LIMIT-TO (SRCTYPE, "j")) AND (EXCLUDE (PUBYEAR, 2022)) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")).

This query was used to retrieve a dataset of this research from the Scopus database. The query was run on January 18, 2022. The search returned a total of 1083 articles (1020 research articles and 63 review articles). The title, abstract and author keywords of these articles were added to the data set for LDA analysis.

2.3 Data pre-processing, analysis and fitting topic modeling

The first stage of the two-stage study was considered as descriptive analysis, and the second stage as topic modeling analysis. Firstly, the descriptive characteristics of the articles in the field of CT were revealed by using the corpus created. The numerical data and frequency information obtained in order to answer the first three research questions were put into tables and graphics. In the second stage, LDA-based topic modeling analysis was conducted to answer the fourth and fifth research questions. At this stage, data/text mining and data pre-processing steps were followed. With these steps, the raw data is transformed into a clean data set (Aggarwal & Zhai, 2013). These steps can be listed as follows: First, the tokenization process was applied to separate the texts into simple words. All words are then converted to lowercase. Later, special characters and punctuation marks in words were eliminated. Words and stop words (a, an, is, the, of, for, etc.) that do not make sense in the text have been omitted. Finally, lemmatization was performed to reach the word stems. After all these preprocessing steps, the final corpus was produced with the remaining words. LDA analysis was performed with the final version of the obtained data set. In the pilot analyses, the words "computational" and "thinking" were observed in almost every topic. Two field experts were consulted and it was decided to add these two words to the stop words as the corpus is directly in this field. Then, LDA analysis was performed again.

Data mining stages and implemetation of LDA algorithm are realized in Python language. While applying the LDA model to the corpus, the values of the parameters that provide the optimization of the model were chosen at the beginning. α, which determines the distribution of topics in documents, and β, which determines the distribution of words in topics, were used as $\alpha = 0.1$ and $\beta = 0.01$ as suggested values for topic modeling of short texts (Blei & Lafferty, 2007; Gurcan, Cagiltay, et al., 2021a). The semantic coherence score was taken into account in determining the optimal number of topics in the LDA (Gurcan, Ozyurt, et al., (Gurcan et al. 2021b) ; Ozyurt & Ayaz, 2022). The optimum level of the coherence score is accepted as 0.7 (Blei et al., 2003). In order to determine the optimal number of topics (K), the LDA model was tried with different K values ranging between 3 and 30. During this process, a coherence score was calculated for each K value. As a result of the iterative analysis, it was seen that the model with 13 topics was ideal (coherence score = 0.487).

While calculating the Acceleration (Acc) value, the slope formula was used and the slope value of the data in a range was taken into account as acceleration. The slope of each topic over time was determined, and an Acc value was calculated in this way. A negative or positive Acc value indicates a decrease or increase in the number of publications on that topic. Volume and slope graphs were created within the topics over time and according to other topic.

Table 1 Distribution of articles in the field of CT by years

Year	n	%
2005and before	3	0.28
2006	1	0.09
2008	4	0.37
2009	11	1.02
2010	5	0.46
2011	10	0.92
2012	6	0.55
2013	15	1.39
2014	32	2.95
2015	31	2.86
2016	56	5.17
2017	72	6.65
2018	99	9.14
2019	154	14.22
2020	237	21.88
2021	347	32.04
Total	1083	100.00

Table 2 Prominent authors in articles in the field of CT and their article numbers

Author	n
Bers, M.U.	11
Yadav, A	10
Román-González, M	8
Basu, S	7
Kong, S.C	7

3 Findings

Firstly, descriptive data obtained from the study are presented. In accordance with this, the annual number of publications, prominent authors, countries and universities; fields and journal information are dealt with to answer the first three research questions. In terms of the answers the fourth and fifth research questions, topic modeling analysis findings are then presented to provide an overall picture of the CT studies.

3.1 Descriptive analysis findings

The distribution and percentages of articles in the field of CT from past to present according to years are given in Table1 (RQ1). As it is seen in Table1, there are a total of 1083 articles in this field (1020 research articles and 63 review articles). Although there was no obvious trend in the first years, it can be said that there is a significant increase in the number of articles every year, especially after 2015, and there is a linear increase in general.

Findings (RQ2) about the prominent authors, countries and universities in the articles in the field of CT are given in Tables2 and 3; Fig.1, respectively. Prominent author in articles in this field is Bers, M.U. (n=11), United States (n=344) is the

Table 3 Prominent countries in articles in the field of CT

Country	n	%
United States	344	31.76
Spain	93	8.59
China	73	6.74
Turkey	68	6.28
South Korea	63	5.82
Taiwan	46	4.25
Italy	41	3.79
United Kingdom	36	3.32
Greece	33	3.05
Malaysia	28	2.59
Total	825	76.18

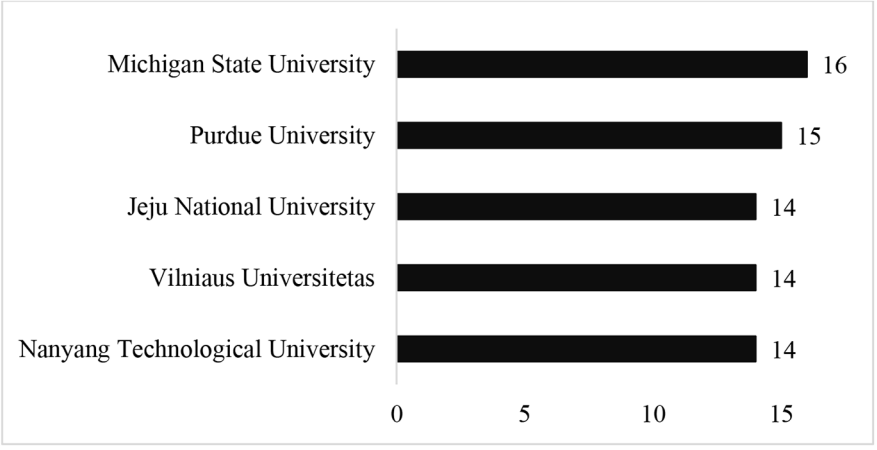

Fig. 1 Top five most-published affiliations and number of publications

prominent country and Michigan State University (n=16) is the prominent university. The most prolific writer, Bers, M.U. is from the United States. Considering the publication origins, the ratio of the number of publications of the top 10 countries with the highest publication rate in the total publications has come out as 76.18%. In other words, nearly three-quarters of 1083 publications originate in the first ten countries.

Findings related to prominent fields and journals in CT articles (RQ3) are presented in Figs.2 and 3, respectively. Figure2 shows the top 10 topic fields covered by the largest number of articles. The majority of the articles were published in the field of social sciences, including educational sciences (n=779). Some studies were classified by Scopus in this way because they were conducted in more than one discipline. Figure3 shows the top 10 journals with the most published articles. The Education and Information Technologies journal published the highest number of articles (n=36), and it is followed by Journal of Educational Computing Research (n=35), Informatics in Education (n=688), and Computers & Education (n=27).

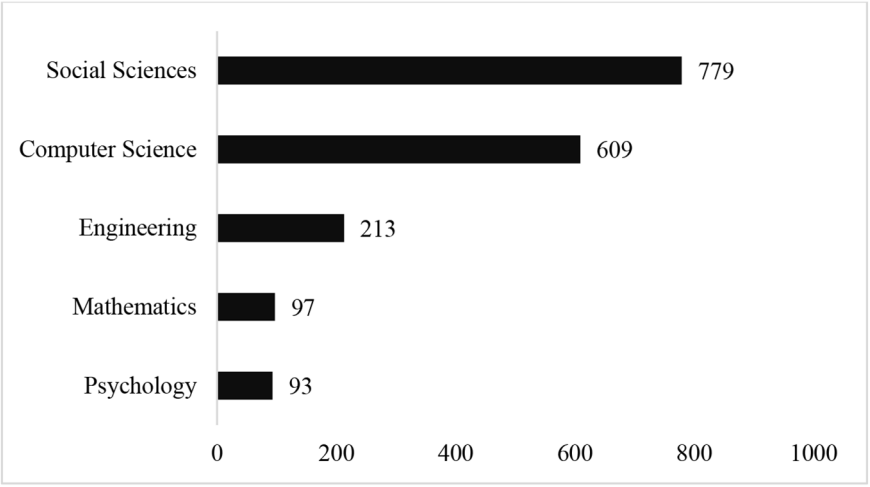

Fig. 2 Top five most-published subject areas and number of publications

3.2 Findings of topic modeling analysis

Findings on prominent topics and research interests (RQ4) and trends (RQ5) in articles in the field of CT are presented in this section. As a result of the LDA-based topic modeling analysis, 13 topics were discovered. The topics were named by three field experts, using the key terms that make up the topics. In calculation of the proportion of each topic, the number of articles published on each topic was taken as a basis. The topics are given rankly in table in accordance with the volume rank. The first 15 terms that make up each topic are listed rankly according to the density of forming that topic.

Table4 shows that the most studied topic in the field of CT is "Game based learning" (20.96%), it is followed by "Programming skills" (17.08%) and "Early child coding" (10.53%). The least studied topic was "Learning assessment" with 2.31% volume. The time period was divided into certain periods in order to determine the distribution of the discovered topics by years, and the trend of each topic within itself and compared to other topics. These periods and the number of articles in each period are given in Table5. The time period, the distribution of the articles by years was taken into account and the years 1987–2005 (it was found appropriate to combine since there were only 3 articles in this period) was determined as the first period. Time period between 2006 and 2021 was divided into four-year periods. The periods were named 1,2,3,4 and 5 by the researchers to express them simply. The duration and number of periods were decided by the researchers and three field experts.

Using the data in Table5, the volume graph and the slope of this graph were calculated by taking into account the article count of each topic within periods. The slope line has also been added to the volume charts created according to the number of articles. The slope value is taken into account as the acceleration. A positive slope value indicates that the topic is accelerated in the positive direction, and a negative

Table 4 Discovered topics, terms forming the topics and volume ratios

Topics	Topic terms	Rate (%)
Game based learning	learning, game, computer, skill, computing, coding, activity, programming, effect, solving, design, development, technology,data, online	20.96%
Programming skills	skill, programming, learning, ability, test, scale, development, solving, score, teaching, item, creativity, factor, developed, significant	17.08%
Early child coding	child, coding, programming, early, learning, young, game, activity, skill, preschool, unplugged, cognitive, teaching, digital, age	10.53%
Game design &programming	game, programming, design, computer, practice, learning, curriculum, development, skill, digital, concept, technology, computing, abstraction, teaching	8.96%
STEM(science, technology, engineering, and mathematics) education	stem, engineering, learning, teaching, activity, computing, teacher, technology, computer, design, student, integration, steam, knowledge,data	7.76%
Algoritm design skills	learning, skill, algorithm, design, programming, development, concept, learner, mathematics, technology, teaching, computer, critical, computing, program	6.65%
Robotic programming	programming, robotics, student, learning, skill, activity, computer, coding, teaching, design, development, primary, teacher, elementary, language	6.00%
Pre-service teacher education	teacher, pre-service,data, teaching, learning, computer, attitude, stem, curriculum, skill, student, digital, development, training, technology	5.26%
Programming knowledge	knowledge, computer, programming, data, teaching, learning, environment, game, problem-solving, algorithm, game-based, technology, strategy, method, skill	4.99%
Pre-service teacher TPACK	pre-service, teacher, knowledge, technology, content,development, practice, teaching, curriculum, data, computing, classroom, lesson, professional, subject	4.16%
Coding in mathematics	coding, mathematics, teacher, computer, mathematical, method, affective, software, critique, teaching, professional, technology, practice, experience, experiment	2.95%
Child coding development	child, coding, engineering, development, activity,experience, childhood, software, computing, community, learning, logistics, stem, computation, concept	2.40%
Learning assesment	assessment, learning, student, literacy, computer, method, design, practice, digital, task, data, skill, environment, ict, concept	2.31%

slope indicates that the topic is accelerated in the negative direction. In other words, the increase in acceleration can be thought of as an increase in the frequency of studying the topic, and a decrease can be considered as a decrease in the frequency of studying. These graphs are given in Fig.4 rankly according to the volume density. While the horizontal axis of the graphs shows the periods, the vertical axis shows the number of publications in that period. The acceleration values of the topics are also shown on the graphs. Slope graphs are used as acceleration. In this way, the acceleration of each topic was calculated.

As seen in Fig.4, “Game based learning”, which is the most voluminous topic, has the highest acceleration within periods (Acc = 38.9). In other words, it is the topic that increases the number of publications the most within the periods. The volume changes and slopes of the topics show similarity according to the periods. As a matter of fact, the least accelerated topic emerged as “Learning assessment” (Acc = 4.3).

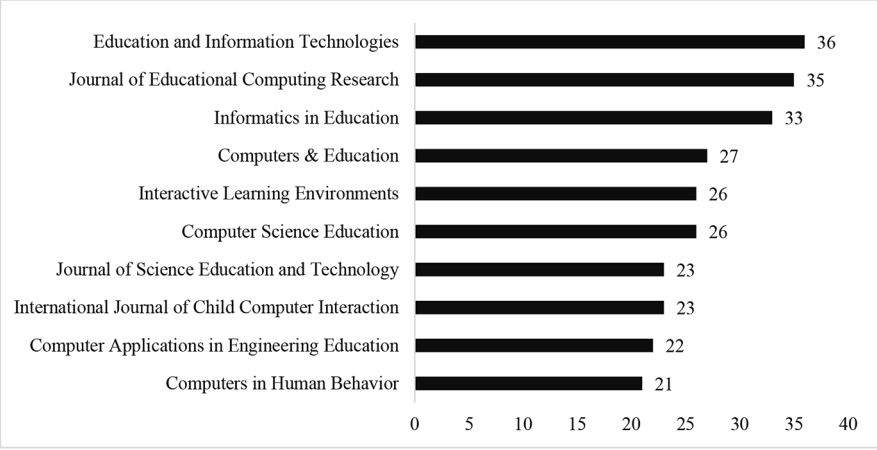

Fig. 3 Top ten most-published journals and number of publications

Table 5 Distribution of the number of articles on the topics according to four-year periods

Topics	Periods					Total
	1987–2005	2006–2009	2010–2013	2014–2017	2018–2021	
	1	2	3	4	5	
Game based learning	1	4	9	31	182	227
Programming skills	0	3	3	27	152	185
Early child coding	0	0	4	18	92	114
Game design &programming	0	3	6	18	70	97
STEM(science, technology, engineering, and mathematics) education	0	3	2	19	60	84
Algoritm design skills	0	1	2	17	52	72
Robotic programming	0	0	2	11	52	65
Pre-service teacher education	0	0	2	9	46	57
Programming knowledge	2	1	0	14	37	54
Pre-service teacher TPACK	0	1	2	11	31	45
Coding in mathematics	0	0	2	5	25	32
Child coding development	0	0	1	6	19	26
Learning assesment	0	0	1	5	19	25
Total	3	16	36	191	837	1083

In addition to the volumes of the topics and their accelerations within themselves, the acceleration of the relevant topic compared to the other topics in the periods was also calculated. In this way, the volume of each topic compared to the other topics in the periods was determined. In this calculation, the percentages of the relevant topic in each period were taken into account. For example, the percentages of the most voluminous topic, “Game based learning”, in each period were 33.33%, 25.00%, 25.00%, 16.23% and 21.74%, respectively. In other words, 21.74% (182/837) of the total number of publications in the last period were made on “Game based learning”. Accordingly, the volume percentage graphs of all topics compared to the other topics

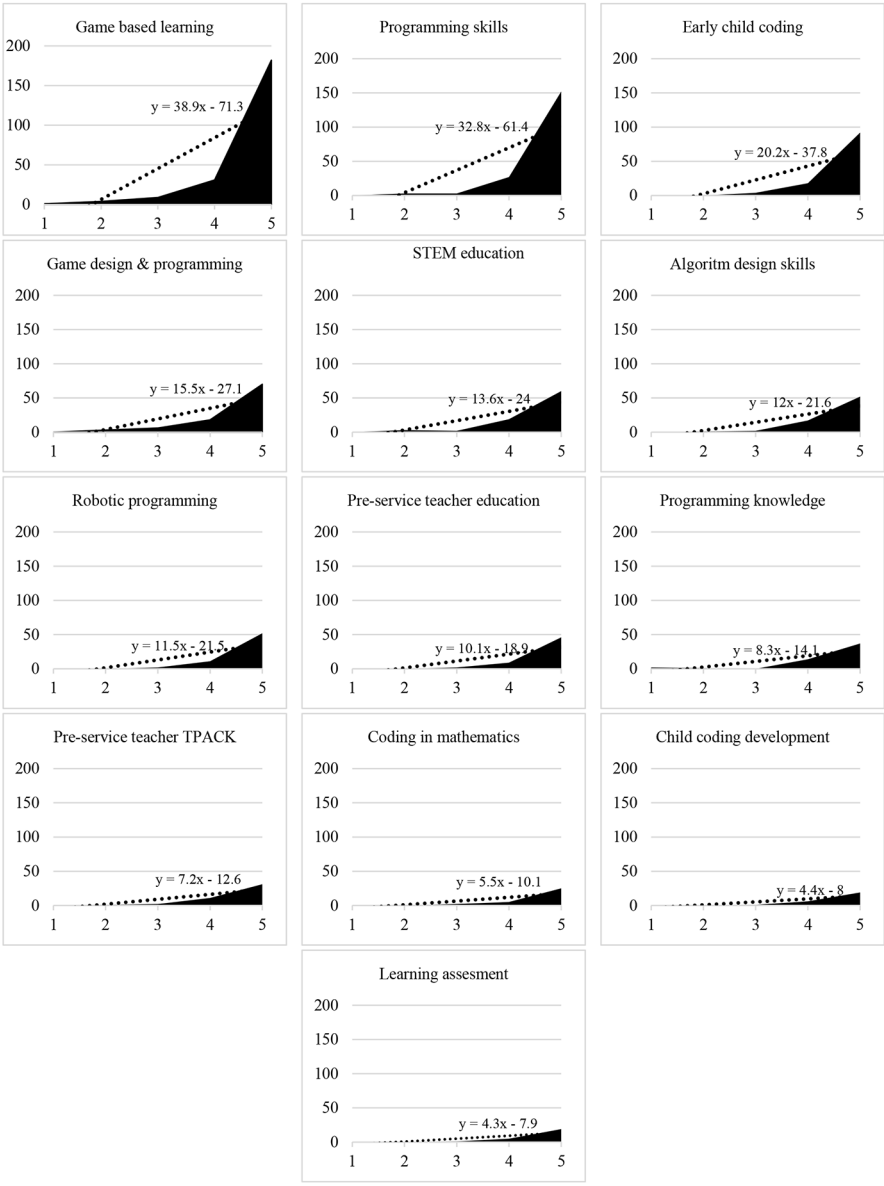

Fig. 4 Volumes and slope graphs of each topic in four-year periods

within periods and their slopes are given in Fig.5. The ranking is given by the magnitude of the accelerations. While the horizontal axis of the graphs shows the periods, the vertical axis shows the percentage of that topic in the relevant period.

As seen in Fig.5, the most accelerated topic compared to other topics is "Programming skills" (Acc = 3.17). In Fig.6, acceleration values of all topics compared to other topics are presented graphically.

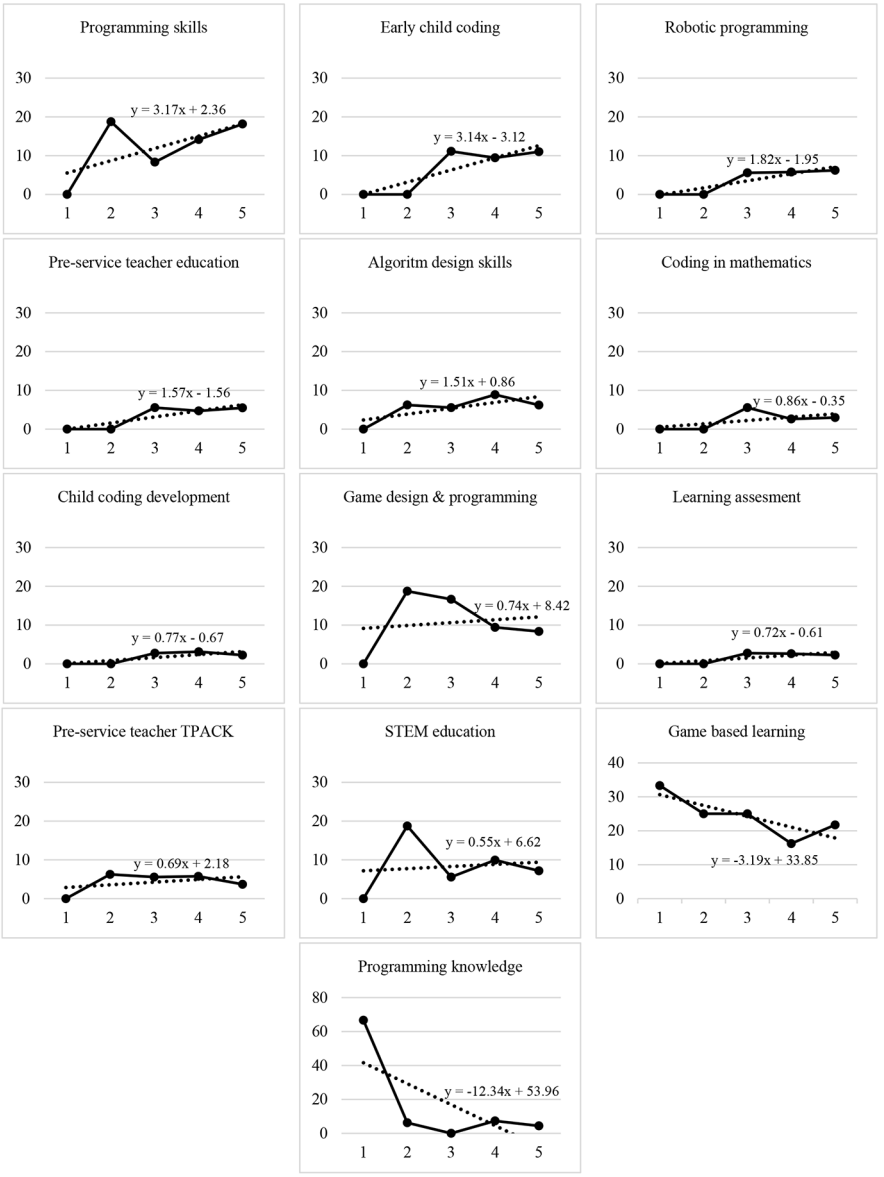

Fig. 5 Percentage and slope graphs of each topic in four-year periods compared to other topics

As can be seen in Fig.6, when the acceleration of the topics relative to each other is examined, the most accelerated topic comes out as “Programming skills”. This is followed by “Early child coding” and “Robotic programming”, respectively. The first two topics who has the most decreased acceleration compared to other topics were “Programming knowledge” and “Game based learning”, respectively. When Figs.4 and 6 are evaluated together, the top five topics with the highest volume can

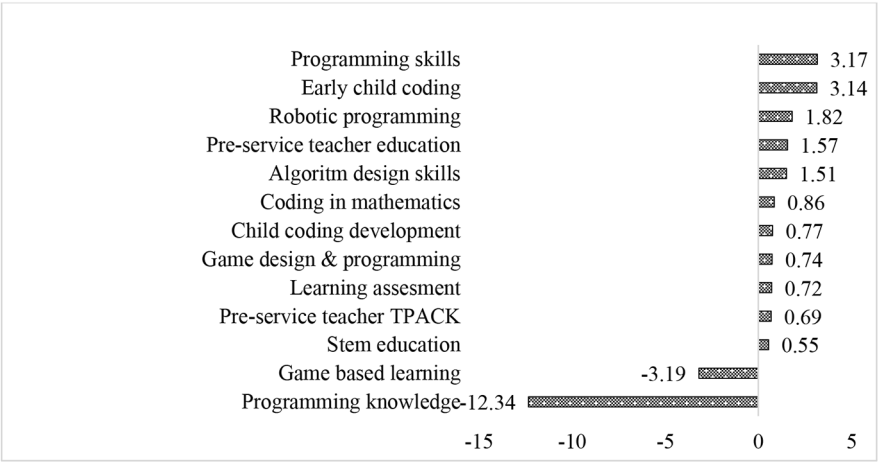

Fig. 6 The acceleration values of each topic compared to other topics

be listed as "Game based learning", "Programming skills", "Early child coding", "Game design & programming" and "STEM education", respectively. While these topics were the most studied and high-volume topics, only two of them ("Programming skills" and "Early child coding") were able to find a place in the top five most accelerated topics. While the topic of "Game based learning" is the most voluminous topic, its acceleration has slowed down compared to other topics. On the other hand, while "Robotic programming" was seventh in the volume, it stands out as the third topic with increasing acceleration compared to other topics. In summary, the most accelerated topics are seen as trending topics. As seen in Fig.6, the first three trending topics stand out as "Programming skills", "Early child coding" and "Robotic programming", respectively.

4 Discussion and conclusions

With this study, descriptive and topic modeling analysis of the articles made in the field of CT from the past to the present was conducted. The aim of the study is to reveal the current situation and to determine the research interests and trends in this field. The study is important in that it is the most comprehensive study with CT articles and the first topic modeling study.

When we look at the number of publications by years (in context RQ1: What is the distribution of CT articles by years?), it is seen that there is a clear and generally linear increase in the number of articles every year, especially after 2015. This situation can be considered as an indication of the importance given to CT research in recent years (Angeli & Giannakos, 2020; Hsu et al., 2018). As a matter of fact, the findings of the study support the conclusion that the number research conducted in the field of CT has increased in recent years. CT is recognized as an important skill of the 21st

century and great importance has been given to this field in recent years (Ching et al., 2018; Voogt et al., 2015; Zhang & Nouri, 2019).

When the prominent authors, universities and countries in the articles in the field of CT are examined together (in context RQ2: Which are the prominent authors, countries and universities in CT articles?), the author with the highest number of articles (n = 11) is Bers, M.U. Although this author's university is not in the top 5 universities (Tufts University), the author is from the United States, the country with the most articles. On the other hand, the second author with the most publications is from Michigan State University (in United States), which has the most publications. Three of the top five most influential authors' studies in this field (Bers, M.U.; Yadav, A.; Román-González, M), are common with the study of (Tekdal, 2021). Since (Tekdal, 2021) obtained the data in June 2020, the difference in authors is natural. On the other hand, while two of the top five universities with the most publications are from the United States, one of them is from South Korea. When compared with the results of (Tekdal, 2021) the prominent countries in the publications in the field of CT, the result that the most active country was the United States is common for both studies. Although the first five countries are the same, it takes the attention that there has been an increase in studies originating from Spain and China in the recent period, and a slowdown in South Korean origins. It is noteworthy that the number of articles originating from the United States is 31.76% of the total number of articles. This may be an indicator of the country's technological and academic superiority (Tekdal, 2021).

When the prominent subject areas and journal in CT articles are examined (in context RQ3: Which topics and journals stand out in CT articles?), it is seen that the topic field of social sciences, including educational sciences, is in the first place. However, the fact that the "Computer science" and "Engineering" topic fields follow "Social sciences" points to the importance and interdisciplinary position of the CT field. This supports the fact that the articles in the field of CT are spread over the different topics and attract researchers from different disciplines (Angeli & Giannakos, 2020; Tekdal, 2021). As a matter of fact, the opinion that CT can be applied in teaching different disciplines is common in the literature (Lyon & Magana, 2020; Tang et al., 2020). Considering the journals in which the articles in the field of CT were published, they were published in 160 different journals. In general, CT-related articles have been published in a wide variety of journals covering many fields such as educational technology, educational sciences, computer science, informatics, science, software, mathematics, and engineering. This situation can be regarded as a proof that the CT field is interdisciplinary. When the top ten journals with the highest number of publications are examined, it should not be ignored that the publications are mostly concentrated in the journals that are the intersection of educational technologies and education and computer science (Tekdal, 2021).

The topic modeling analysis (in context RQ4: What are the prominent topics in CT articles?) findings showed that the articles in the field of CT were grouped under 13 main topics. Among these topics, the first three topics with the highest volume, in other words, the most studied topics, came out as "Game based learning", "Programming skills", and "Early child coding", respectively. Besides, "Game design & programming", "STEM education", "Algorithm design skills" and "Robotic programming" follow these topics. The least voluminous topic is "Learning assessment".

When “Game based learning” and “Game design & programming”, which are among the top five most voluminous topics, are considered together, it is seen that game design, game programming and game-based learning have an important place in the CT field (Israel-Fishelson & Hershkovitz, 2020). This result supports the studies in the literature that emphasize the importance of the concept of game in the development of CT skills. As a matter of fact, there are many studies on game design as a pedagogical framework for the development of CT skills and suggestions for learning through play (Israel-Fishelson & Hershkovitz, 2020; Turchi et al., 2019; Weintrop et al., 2016). In addition, it is also mentioned in the literature that games have an important place in programming learning (Hooshyar et al., 2021; Hsu et al., 2018; Kazimoglu et al., 2012; Lee et al., 2014; Turchi et al., 2019). In this respect, it is natural that game-related topics have emerged among the most voluminous topics in the field of CT. In addition, “Programming skills”, “Early child coding”, “STEM education” and “Robotic programming” can be considered as topics that can be evaluated together. The fact that CT is intertwined with programming supports this situation. The idea that coding and programming have an important place in the development of CT skills is widely accepted (García-Peñalvo & Mendes, 2018; Lye & Koh, 2014; Pala & Mıhcı Türker, 2021; Papadakis et al., 2016). During programming and coding, students are exposed to CT, which is important in the development of CT skills (Grover & Pea, 2013; Kafai et al., 2010; Wei et al., 2021; Wing, 2006). “Early child coding”, “STEM” and “Robotic programming” topics are also related to each other and can be evaluated together. It is emphasized that the way to be successful in STEM education is to make CT a part of all education (Li et al., 2020a; Weintrop et al., 2016). Accordingly, in recent years, there has been a rising trend in STEM fields to integrate computing (hence CT) into disciplinary education (Li et al., 2020b; Wang et al., 2021).In addition, early child coding and robotics are highlighted as an emerging approach for inclusion in STEM education (Ching et al., 2019). In fact, students can find solutions for real-life problems through the concepts and practices from relavent STEM topics thanks to contribution of robotic activities to the integrated STEM education (Ching et al., 2019; Kucuk & Sisman, 2020). When the findings of the study are evaluated as a whole, it can be said that these prominent topics in the field of CT support their importance in the literature.

Finally, when the acceleration of the topics in the CT field is examined (in context RQ5: What are the trend topics in CT articles?), the first three topics that accelerated the most (increasing in volume among the topics studied in the field) emerged as “Programming skills”, “Early child coding” and “robotic programming”, respectively. The top three trending topics are directly related to coding/programming. This proves that programming is widely associated with CT (Voogt et al., 2015). In addition, coding/programming provides the necessary mechanisms to implement CT concepts and applications and supports the development of CT (Basogain et al., 2018; Lye & Koh, 2014; Tikva & Tambouris, 2021). The efforts to implement early age programming teaching all over the world confirm these results. The topic of “Pre-service teacher education”, which follows the programming topics, is also noteworthy. As a matter of fact, it is possible to mention studies in the literature emphasizing the necessity of adding CT and programming modules to pre-service teacher education (Boulden et al., 2021; Sands et al., 2018; Umutlu, 2021; Yadav et al., 2017).

Because it is an expected situation that the teachers who will teach these skills to the students also need to have knowledge in this field. In general, the two topics whose acceleration decreased the most (whose volumes among the topics studied are decreasing) emerged as "Game based learning" and "Programming knowledge". While "Game based learning" is the most voluminous topic, it is interesting that its density to be studied has decreased compared to other topics. This situation can be interpreted as this field has reached saturation in general and new research areas are opened. In addition, regarding "Programming knowledge", it can be interpreted that this topic has had a stable situation over time, as it was also in the first periods. The acceleration of the "Game based learning" topic (its ratio relative to other topics) generally shows a consistent decrease over the periods. The topic of "Programming knowledge" showed a sharp decrease at the end of the first period. After the second period, nearly constant development. Although the sharp decrease in the first period shows the decrease in general, the almost constant change in the following years can be taken into account.

4.1 Implications of this study

In this section, the implication of the study and the current situation are presented in line with the results of the study and discussion, and inferences for the future are made. Considering the number of articles by years, it can be said that there is a linear increase in the number of articles every year, especially after 2015. Accordingly, it is possible to say that the CT field is still developing. Although it is an interdisciplinary field, educational technologies journals have come to the fore in the field of CT, which is led by social sciences including educational sciences. In this context, it can be expected that these studies will continue to be exist in the field of educational sciences and technologies. In terms of the origins of publications in this field, "United States", "Spain" and "China" take the lead.

In the context of topic modeling analysis, it was seen that the topics, "Game based learning", "Programming skills" and "Early child coding" were the most voluminous topics, respectively. Although these topics are the most widely published topics, it has been seen that these three topics are also being studied more and more at the same time. In other words, the number of publications on these topics has increased over time. It can be expected that this situation will continue in the near future, as they are the most voluminous topics and the intensity of their work increases over time. In addition to these, a similar situation was encountered when an analysis was realized about the topics that came to the fore among other topics and increased their rate/intensity of study compared to other topics. As a matter of fact, the top three topics, whose intensity of study increased the most compared to other topics are "Programming skills", "Early child coding" and "Robotic programming". Two of these topics ("Programming skills" and "Early child coding") are also the most studied topics. Apart from these, "Robotic programming" is remarkable among the prominent topics. It is recommended to monitor this topic together with the other two topics in the following years and to follow its growth.

4.2 Limitations and future works

This study aims to examine the articles in the field of CT from the past to the present (until the end of 2021). With descriptive analysis, the main bibliometric characteristics of the field were found out. With the topic modeling analysis, which takes bibliometric studies one step further, current situation of the field, research interests and trends in this field and its development are revealed. The most innovative aspect of the study is that it is the first study in this field to include topic modeling analysis. The fact that only journal articles were considered in the study in order to improve the quality of the research can be regarded as a limitation. All document types can be analyzed in future studies. Another point is that the similar study can be repeated several years apart and the changes in trends can be given comparatively. On the other hand, in future studies, more in-depth semantic analyzes may be possible by making similar analyzes on more specific sub-topics of the CT field.

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict interest.

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