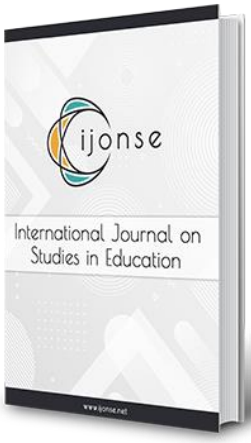

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Bibliometric Analysis of Artificial Intelligence Studies in Computational Thinking

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Bibliometric Analysis of Artificial Intelligence Studies in Computational Thinking

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Abstract

Computational thinking is an approach used to solve complex problems with basic skills such as decomposition, pattern recognition, abstraction and algorithm design. Especially artificial intelligence and its sub-fields make significant contributions to the development of these skills. This study aims to evaluate the research in the field of artificial intelligence in the computational thinking process through bibliometric analysis. The data of the study were obtained from the Web of Science (WoS) database on May 1, 2024. The VOSviewer software program, which is frequently used in bibliometric analysis and can be used free of charge, was used to analyze the data obtained from the WoS database. Analyses using the data obtained from the WoS database enabled the analysis of research in this field in terms of countries, authors, co-authorship status, publication journals, publication years and keywords. The findings of the study show that Taiwan is the country with the highest number of studies in this field, while Spain is the country with the highest number of citations. Hooshyar, D and Hsu, T are among the authors who contributed to the most publications. Collaboration plays an important role in research and Lai, C stands out as the author with the most co-authorship. Education and Information Technologies and Kunstliche Intelligenz are among the journals where the most studies are published. As a result of the examination of the 5 most cited studies, it was determined that different research methods and participant groups were used, data collection tools varied and different data analysis methods were used. These studies provide a broad perspective on artificial intelligence studies in the field of computational thinking and make important contributions to the literature in this field.

Introduction

Computational thinking refers to the problem-solving approach used by computer scientists and software engineers to tackle complex problems using algorithms, abstraction and decomposition. Computational thinking involves breaking complex problems into smaller, more manageable pieces, identifying patterns and trends, and designing algorithms to solve them (Barr & Stephenson, 2011). Computational thinking is not limited to computer science; it is defined as a transferable skill that can be applied to a range of disciplines and real-world contexts, including business, engineering and scientific research (Wing, 2006). According to Wing (2006), computational

thinking involves the use of abstraction and modeling to represent real-world problems in a simplified form, which enables the application of logical and analytical thinking to solve them.

Computational thinking also involves the use of algorithms to automate repetitive tasks to make them more efficient and error-free (Denning, 2009). Computational thinking is recognized as a critical skill in the 21st century where technology is transforming the way we work, communicate and live our lives. Therefore, there is an increasing need for computational thinking skills in the digital age (Grover & Pea, 2013).

Computational thinking focuses on four key skills: decomposition, pattern recognition, pattern abstraction, and algorithm design. Decomposition skill refers to the ability to break down complex problems or tasks into smaller, more manageable components to better understand and solve them (Smith, 2018). According to the research conducted by Johnson and Lee (2019), decomposition skill is a fundamental cognitive skill that plays an important role in problem solving, critical thinking and decision making. Pattern recognition is the cognitive ability to identify and distinguish recurring patterns or regularities in information or data and allows individuals to make sense of complex and diverse stimuli (Gagné & Smith, 2017).

Research by Liang and Zhu (2018) showed that pattern recognition is a fundamental cognitive process that plays a crucial role in various domains such as language acquisition, visual perception, decision making, and problem solving. Pattern abstraction refers to the cognitive process of extracting and generalizing common features or underlying structures from a set of related patterns or stimuli (Smith & Johnson, 2019). It involves the ability to identify commonalities and abstract basic knowledge from a variety of examples, allowing individuals to create higher-level representations or mental models that capture the essence of patterns or information (Jones & Chen, 2020). Pattern abstraction is a crucial cognitive skill that enables individuals to recognize and apply abstract concepts, rules and principles in various domains such as problem-solving, decision making and learning. Algorithm design is the step-by-step demonstration of the planned operations in the design of a problem to be solved or a process planned to be implemented and how to reach the result (Üzümcü & Erdal, 2018).

Computational thinking has a significant impact on AI and contributes to the use, recognition and evaluation of AI-based technologies (Celik, 2023). Artificial intelligence and its subfields are also largely based on concepts such as abstraction, data collection and analysis, algorithms and automation (Lozano et al., 2021). These concepts are also considered to be essential components of the computational thinking process. The field of artificial intelligence is a comprehensive interdisciplinary field that plays an important role in the development of computational thinking capabilities. This field is well aligned with the factors of computational thinking and therefore helps to develop computational thinking and algorithmic thinking (Huang & Qiao, 2022). When we look at the studies on artificial intelligence in the field of computational thinking, there is no study that examines it with bibliometric analysis method.

This article presents a bibliometric analysis of artificial intelligence studies in the field of computational thinking to address the literature gap. For this purpose, answers to the following research questions were sought:

1) Which countries have done the most work in the field of artificial intelligence in the computational

thinking process?

2) Which authors have contributed the most publications in the field of artificial intelligence in the computational thinking process?
3) What is the status of co-authorship in studies on artificial intelligence in the computational thinking process?
4) Which journals have published the most in the field of artificial intelligence in the computational thinking process?
5) What is the distribution of studies on artificial intelligence in the computational thinking process according to years?
6) Which keywords are most commonly used in studies on artificial intelligence in the computational thinking process?
7) What are the 5 most cited articles in the field of artificial intelligence in the computational thinking process?
    a) Which research methods were used in the 5 most cited articles?
    b) Who are the contributors of the 5 most cited articles?
    c) Which data collection tools were used in the 5 most cited articles?
    d) Which data analysis methods were used in the 5 most cited articles?

Method

A bibliometric analysis approach was used to examine research on artificial intelligence studies in the field of computational thinking. Bibliometric analysis is a very popular method in recent years to search and analyze large volumes of scientific data (Donthu et al., 2021). Researchers use the bibliometric analysis method to reveal research components, to examine the specific field in the existing literature (Donthu et al., 2021; Verma & Gustafsson, 2020).

Bibliometric analysis is used for mathematical and statistical techniques to quantitatively analyze the bibliographic characteristics of a literature in terms of subject area, countries or regions, keywords and authors (Hawkins, 2001; Pritchard, 1969; Zou et al., 2022). The systematic review approach is another method used in the research in order to examine in depth the most cited studies among the research on artificial intelligence studies in the field of computational thinking. The systematic review approach is a research method that involves the unbiased synthesis of findings by answering predetermined research questions to bring together the results of individual studies (Higgins & Green, 2011).

Article Selection Process

The data for this study were retrieved from the Web of Science (WoS) database on May 1, 2024. WoS database was chosen as the search engine because it is one of the most widely used databases for analyzing scientific publications, covers international journals and has high quality publications (Chang & Yang, 2022; Yang et al., 2013). The keywords "computational thinking", "artificial intelligence" and "ai" were searched through the

database.

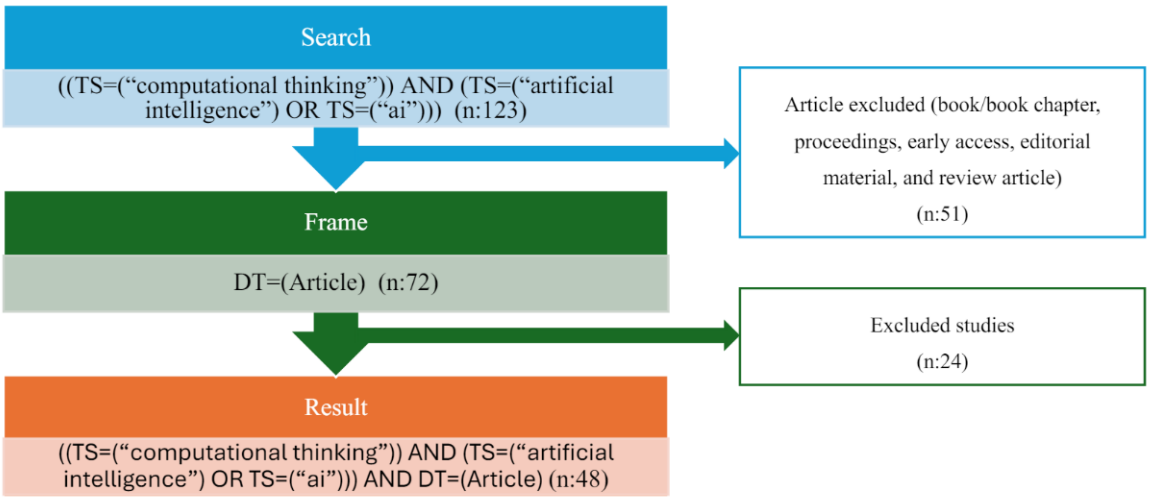

Figure 1. Article Selection Process

During the search process, 123 studies were reached. At the screening stage, 72 article studies were included in the review, excluding studies such as books/book chapters, proceedings, early access, editorial material and review the article. In the review phase, 24 studies were excluded because they were outside the subject area and the review was completed with 48 studies (see Figure 1).

Data Analysis

In this study, VOSviewer (www.vosviewer.com) software program (version 1.6.20), which is frequently used in bibliometric analysis, was used to examine and visualize the bibliometric analysis of the data obtained from the WoS database. VOSviewer software is highly functional software for viewing and interpreting bibliometric maps (Van Eck & Waltman, 2010). It is a program used for clustering data, displaying data in different colors according to cluster topics, mapping method, showing the distance between two items (Nunen et al., 2018). Within the scope of this study, VOSviewer software was used to analyze and visualize the relationships between terms such as bibliometric matching of countries, bibliometric matching of authors, interaction factors of journals and journals, years of publication of studies, and keywords used.

Results

1) Which countries have done the most work in the field of artificial intelligence in the computational thinking process?

Taiwan has conducted the most studies on the computational thinking process with 11 studies. China came second with nine studies. The USA and Spain conducted six studies each and the rest of the countries conducted three or less studies. The most cited country is Spain with 92 (see Figure 2).

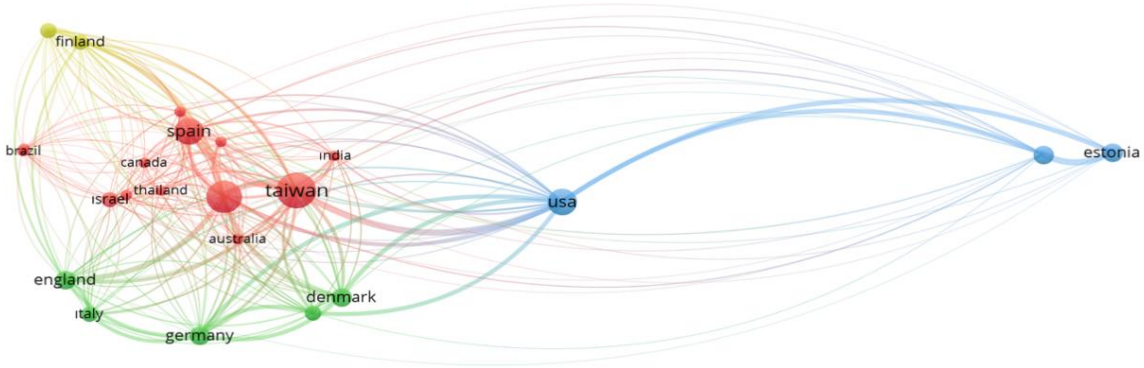

Figure 2. Countries with the Most Studies

2) Which authors have contributed the most publications in the field of artificial intelligence in the computational thinking process?

When we look at the authors who contributed to the most publications in Table 1, Hooshyar and Hsu are in the first place with three publications. Then the authors who contributed the most publications are Lai, Levin, Yang and Zhong with two publications.

Table 1. Authors Contributing to the Most Publications

Author	Number of publications (*f*)
Hooshyar, D	3
Hsu, TC	3
Chen, SY	2
Lai, CF	2
Levin, I	2
Yang, Y	2
Zhong, HX	2

3) What is the status of co-authorship in studies on artificial intelligence in the computational thinking process?

When we look at the co-authorship status, it is seen that Lai is the author with the most co-authorship, and when we look at the co-authorship network analysis, it is seen that many authors publish with each other (see Figure 3).

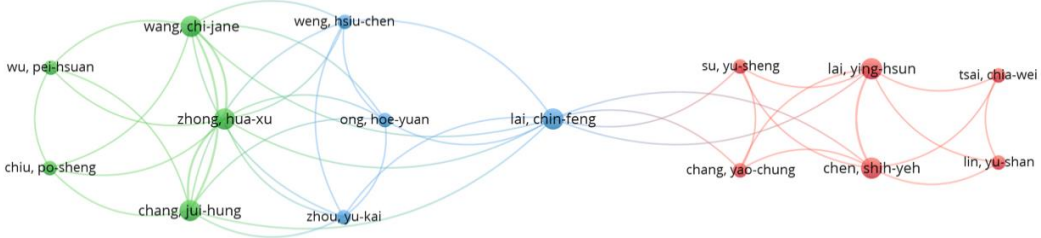

Figure 3. Co-authorship Status

4) Which journals have published the most in the field of artificial intelligence in the computational thinking process?

Table 2 shows that the journals with the highest number of publications are Education and information technologies four publications, Kunstliche intelligenz four publications, Frontiers in psychology three publications, Applied sciences-basel two publications, Educational technology research and development two publications, IEEE access two publications and Interactive learning environments two publications.

Table 2. Journals with the Most Publications

Journal	Number of publications(f)
Education and information technologies	4
Kunstliche intelligenz	4
Frontiers in psychology	3
Applied sciences-basel	2
Educational technology research and development	2
IEEE access	2
Interactive learning environments	2

5) What is the distribution of studies on artificial intelligence in the computational thinking process according to years?

When the distribution of studies by years is analyzed, it is seen that the most publications were made in 2023 with 14 publications. Since 2020, it is seen that 12 publications were made in the first five months of 2024, where the number of publications has been increasing with an upward trend. It can be said that the number of studies in this field has increased over the years after 2020 (see Figure 4).

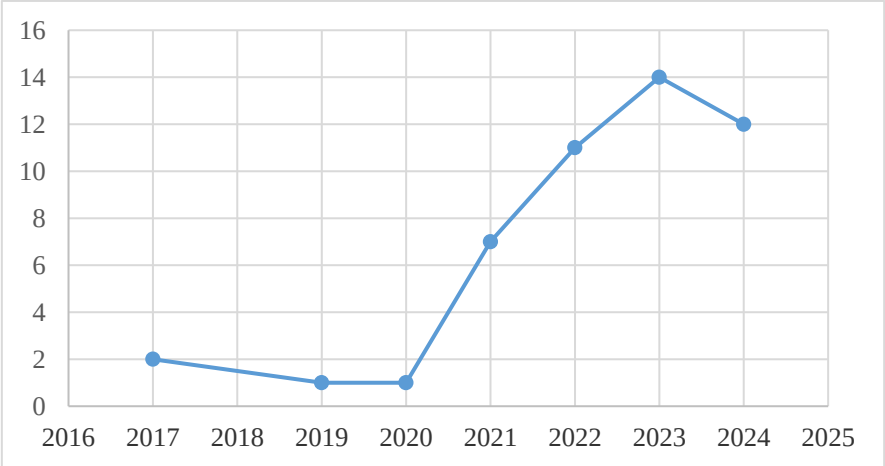

Figure 4. Distribution of Publications by Years

6) Which keywords are most commonly used in studies on artificial intelligence in the computational thinking process?

When we look at the most used keywords in the studies, computational thinking ranks first with 30 uses. The second most used keyword was artificial intelligence, the third was machine learning and the fourth was programming. When all these are analyzed, it is thought that the studies were selected in accordance with the purpose of the research (see Figure 5).

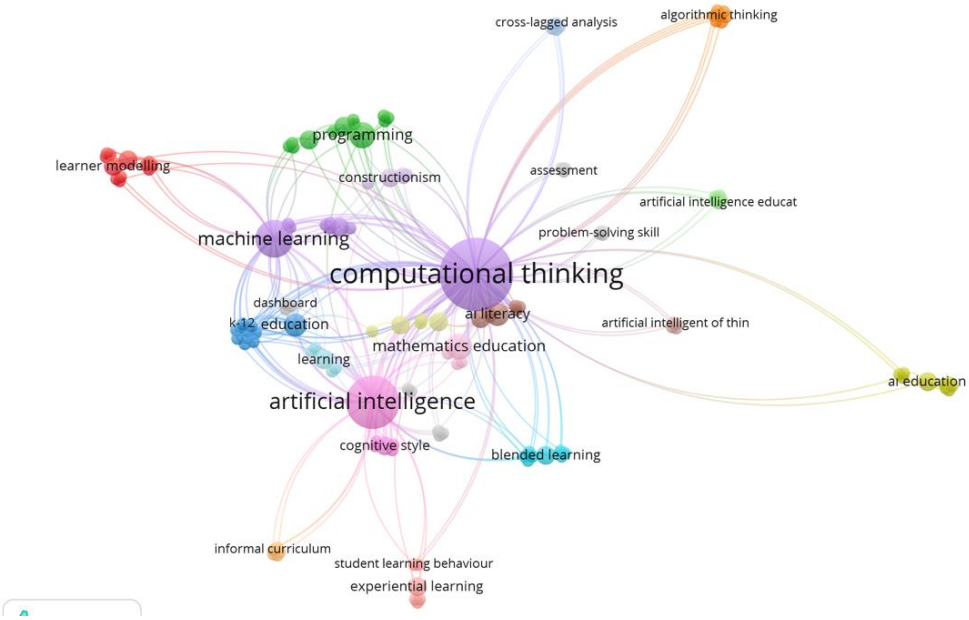

Figure 5. The Most Commonly Used Keywords in the Studies

7) What are the 5 most cited papers in the field of artificial intelligence in the computational thinking process?

Table 3. Top 5 Most Cited Publications

Number	Title	Author(s)	Total Citations	Total Citations Per Year
1	Gentle introduction to artificial intelligence for high-school students using scratch	Estevez, Garate & Graña (2019)	44	8,80
2	Study on Enhancing AIoT Computational Thinking Skills by plot image-based VR	Lai et al. (2021)	38	12,66
3	Teaching Machine Learning in K-12 Classroom: Pedagogical and Technological Trajectories for Artificial Intelligence Education	Tedre et al. (2021)	37	12,33
4	Advanced technologies to face the challenge of educational innovation	Espinosa & Cartagena (2021)	33	11
5	Artificial intelligence, computational thinking, and mathematics education	Gadanidis (2017)	32	4,57

When we examine the five most published articles in Table 3, we see that these are Gentle introduction to artificial intelligence for high-school students using scratch (Estevez, Garate & Graña, 2019) published in 2019, secondly Study on enhancing AIoT computational thinking skills by plot image-based VR (Lai et al., 2021) published in 2021, thirdly Teaching machine learning in k-12 classroom: pedagogical and technological trajectories for artificial intelligence education (Tedre et al., 2021), fourth is Advanced technologies to face the challenge of educational innovation (Espinosa & Cartagena, 2021) published in 2021, and fifth is Artificial intelligence, computational thinking, and mathematics education (Gadanidis, 2017) published in 2017.

a) Which research methods were used in the 5 most cited articles?

Table 4 presents the research methods used in the five most cited articles. In the first most cited article, design based research (DBR) was used. In the second article, experimental research was used. In the third article, systematic review was used. In the fourth article, analytical review method was used. The fifth article was written with literature review.

Table 4. Research Methods Used in the 5 Most Cited Articles

Number	Method
1	Design based research (DBR)
2	Experimental research
3	Systematic review
4	Analytical review method
5	Literature review

b) Who are the contributors of the 5 most cited articles?

When we examine the participants of the five most cited articles in Table 5, in the first most cited article, a total of 37 students, 40% female and 60% male, aged 16-17, studying in the technology branch of a local high school.

Table 5. Contributors of the 5 Most Cited Papers

Number	Participant
1	37 students of the technological branch of a local high school (16-17 years old, 40% female 60% male)
2	85 students attending the IoT Applications and Applications course in the Department of Information Engineering (experimental group: 40, control group: 45)
3	-
4	-
5	-

In the second article, 85 students participated in the IoT applications and applications course at the Department of Informatics Engineering, 40 of them in the experimental group and 45 in the control group. In the third, fourth and fifth articles, no participant information was provided due to the nature of the studies.

c) Which data collection tools were used in the 5 most cited articles?

Table 6 presents the data collection tools used in the five most cited articles. In the first most cited article, questionnaire, in the second article, VR training materials and AIoT platform were used. No data collection tool information was provided in the third, fourth and fifth articles.

Table 6. Data Collection Tools Used in the 5 Most Cited Articles

Number	Data collection tool
1	Questionnaire
2	VR instructing materials, AIoT platform
3	-
4	-
5	-

d) Which data analysis methods were used in the 5 most cited articles?

Table 7 presents the data analysis methods used in the five most cited articles. In the first most cited article, Likert scale and Fisher test were used as data analysis methods. In the second article, analysis of covariance (ANCOVA) method was used. In the third, fourth and fifth articles, no data analysis method information was given.

Table 7. Data Analysis Methods used in the 5 Most Cited Articles

Number	Data analysis method
1	Likert scale, Fisher test
2	Analysis of covariance (ANCOVA)
3	-
4	-
5	-

Discussion and Conclusion

Studies on artificial intelligence are increasing at a rapid pace every day. Computational thinking has a significant impact on the use, recognition and evaluation of artificial intelligence-based technologies (Celik, 2023). This research presents the results of the evaluation of the research on artificial intelligence studies in the field of computational thinking with a bibliometric analysis approach.

Within the scope of the findings obtained from the research, it was seen that Taiwan (f=11) was the country with the highest number of studies in the field of artificial intelligence in the computational thinking process. This can be considered as an indicator of the importance given to computational thinking and artificial intelligence by the education and research policies in Taiwan. Taiwan is followed by China (f=9), USA (f=6) and Spain (f=6) as the countries with the highest number of studies. In the remaining countries, three or fewer studies were found. This result shows that artificial intelligence studies in the field of computational thinking have become widespread worldwide, but not enough research has been conducted in some countries. It reveals that more research needs to be done for the global adoption and dissemination of artificial intelligence studies in the field of computational thinking and that more investment is needed in this field, especially in countries with low number of studies.

The country with the highest number of citations in the studies is Spain (f=92). Spain's studies in this field have attracted great attention in the international academic arena and received significant citations. This result shows the quality and effectiveness of Spain's research on the computational thinking process. It can be said that Spain's studies in this field will provide reference to studies in other countries and will make a significant contribution to the scientific literature in this field.

When the author contributions of the studies on artificial intelligence studies in the field of computational thinking are analyzed, it is seen that certain authors have made significant contributions to this field. According to the findings of the study, Hooshyar (f=3) and Hsu (f=3) ranked first among the authors who contributed the most publications. Following Hooshyar and Hsu, other authors who contributed to the most publications are Lai (f=2), Levin (f=2), Yang (f=2), and Zhong (f=2). These findings show that the work of these authors is important for the studies of artificial intelligence in the computational thinking process to take place more in the literature and for the studies to continue.

When the co-authorship status of the studies was examined, it was seen that certain authors were in collaboration in this field and Lai was the author with the highest number of co-authorships. The fact that Lai collaborated with a large number of researchers in his studies shows that this author's network in the field is wide and his collaboration capacity is high. In the findings, when the co-authorship network analysis was analyzed, it was seen that many authors published with each other in this field. This finding reveals that research on artificial intelligence studies in the field of computational thinking is largely carried out through collaboration.

When the journals in which studies on artificial intelligence studies in the field of computational thinking were published were examined, it was seen that certain journals stand out in this field. The journals with the most publications are Education and Information Technologies (f=4), Kunstliche intelligenz (f=4), Frontiers in psychology (f=3), Applied sciences-basel (f=2), Educational technology research and development (f=2), IEEE access (f=2) and Interactive learning environments (f=2). The fact that these journals support research on artificial intelligence studies in the field of computational thinking shows that they are important publishing platforms in this field.

With the increasing importance of the computational thinking process and the acceleration of studies in the field

of artificial intelligence, there has been a significant increase in the number of publications of research in this field. When the distribution of the studies according to years is analyzed, it is seen that the most publications were made in 2023 (f=14). The fact that 12 publications were made in the first five months of 2024 shows that this increase will continue, and this number may increase even more by the end of 2024.

When the keyword analysis of the studies was examined, it was seen that the most used keywords were at the center of the research topic. The keyword "computational thinking" (f=30) ranked first among the keywords used in the studies. The second keyword "artificial intelligence" shows how artificial intelligence is related to the computational thinking process and shows that the research in this field is addressed in terms of artificial intelligence.

Within the scope of the research, the 5 most cited studies were listed and the research methods, participants, data collection tools, and data analysis methods used in the studies were examined in depth using a systematic review approach. It was seen that design-based research (DBR), experimental research, systematic review, analytical review method and literature review research methods were used in the most cited articles. In the first two most cited articles, it was seen that there were participants at high school and university level, questionnaire and VR instructing materials, AIoT platform tools were used as data collection tools, likert scale, fisher test and analysis of covariance (ANCOVA) data analysis methods were used. In the other three articles, information about the participants, data collection tools, and data analysis methods were not provided due to the nature of the studies. As a result, the use of different research methods and different participant groups in the most cited studies make important contributions to the literature in this field. The studies conducted using systematic review, analytical review method and literature review research methods provide a broad perspective on artificial intelligence studies in the field of computational thinking and draw attention to the importance of studies in this field.

Recommendations

Recommendations based on the results of the study are given below:

- More work is needed in this topic. Studies both in different countries and with different research methods can contribute to the topic.
- The number of studies based on quantitative methods is higher than qualitative ones. Research can be conducted using mixed methods, taking advantage of both qualitative and quantitative methods.
- It is obvious that studies in the field of AI, which has come to the fore in recent years, will direct future research. Studies in which participant numbers and groups are diverse are important for future studies.

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