

Technology Use in Primary School Science Education: Bibliometric and Descriptive Analysis

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Research article

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Abstract

In this study, it was intended to reveal the general trend of the research on the use of technology in primary school science education in the last 25 years (2000-2024). For this purpose, bibliometric analysis of the data of 115 studies from the Web of Science (WoS) database using the developed parameter was carried out in the VOSviewer program, and descriptive analysis of 107 studies whose full texts were accessed was performed using Excel. As a result of the analysis, it was determined that the number of studies on the related topic has increased in recent years. The most frequently used keywords in these studies were “*science education*”, “*augmented reality*”, “*primary school*” and “*science learning*”. It was also found that Taiwan, People R China and USA were the most productive countries and Hwang, Gwo-Jen, Chen, Chih-Hung and Tsai, Chin-Chung were the most influential authors in this field. It was determined that the most frequently used technologies in these studies were “*multimedia technologies*”, “*technology-supported teaching*” and “*augmented reality*” and “*success/learning*”, “*opinion/experience*” and “*motivation*” were the most frequently examined variables. These results provided a detailed examination of the use of technology in primary school science teaching.

Keywords: Elementary education, augmented and virtual reality, media in education, mobile learning, simulations

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Introduction

Children ask questions to adults after they begin to speak in order to get to know the environment in which they live (Çetin & Koyuncuoğlu, 2013). For example, they ask questions such as “How does day and night come about?”, “Why do we see the moon at night?”, “Why do flowers wither?”, “Why do birds fly?”, “How do bees make honey?”, “Why does the moon change shape?” and many others. It can be argued that children's sense of curiosity is effective in their expectations of explanations for the observations they have made. The process of observing an event, asking questions, reaching answers and evaluating these answers can be partially compared to the processes experienced by scientists. Therefore, it would be possible to think of children as little scientists (Ergül et al., 2011). Science will pave the way for children to explore the world they live in and the events that occur in this world within a cause-and-effect relationship (Ceylan, Kahraman & Ülker, 2015). Thus, children will have the opportunity to experience the experiences of scientists.

In the science teaching process, by nurturing students' natural curiosity and supporting their participation in scientific activities (Fazio, Di Paola & Battaglia, 2020), students can acquire scientific knowledge and concepts as well as some skills and behaviors. Scientific process skills may be the first of these skills that come to mind due to students' curiosity about the environment they live in and their search for cause-effect connections by making observations. Because it is seen that science curricula have been enriched in terms of scientific process skills over time (Demir & Basturk, 2016). Accordingly, it can be said that scientific process skills have developed in the science teaching process (Choirunnisa, Prabowo & Suryanti, 2017; Yeşilçebe Bıyık & Şenel, 2019). Scientific process skills include sub-skills such as observation, measurement, classification, communication, prediction or inference skills. In order for students to experience these skills from childhood, it is important for them to be introduced to scientific process skills from primary school (Choirunnisa, Prabowo & Suryanti, 2017).

One of the main goals of science education is to develop scientific literacy skills (Osborne, 2007; Vieira & Tenreiro-Vieira, 2016). When the scope of scientific literacy is examined, it can be argued that science education is important in helping students acquire this skill. Scientific literacy encompasses the ability to distinguish science from non-science, understand science and its applications, recognize situations considered scientific, think scientifically, and use scientific knowledge to solve problems. These skills also include evaluating social problems on a scientific basis, valuing science, being knowledgeable about both the risks and benefits of science, and using critical thinking skills related to science (Norris & Phillips, 2003). It can be expected that the opportunities that will be offered to students instead of ordinary teaching in the science education process will affect scientific literacy. For example, when a student uses justifications, supports, rebuttals and limitations (Toulmin, 2003) while producing an argument, he/she will engage in a detailed thinking process about a situation and try to convince his/her peers about his/her claim based on scientific grounds. On the other hand, their peers will consider the claim from a scientific framework and critically evaluate the accuracy of this claim. Therefore, it can be argued that scientific literacy is determined by the quality of science education (Crowell & Schunn, 2016) and the various opportunities offered to students rather than the quantity of science education. These opportunities can be provided by utilizing various methods and techniques in science education, such as experiment/laboratory practices, STEM, argumentation, projects, concept maps, and analogy. Moreover, it can be said that the quality of science education can be improved by integrating technological developments into the teaching environment. When the literature is examined, it is seen that the use of technology in science education not only affects scientific process skills (Osman & Vebrianto, 2013; Demirçalı & Selvi, 2022) and scientific literacy (Zárate-Moedano, Canchola-Magdaleno & Suarez-Medellín, 2023; Litina & Rubene, 2024) but also achievement (Asan, 2007; Liu et al., 2022; Liu et al., 2024), performance (Herga, Glažar & Dinevski, 2015), inquiry (Wu et al., 2023), motivation (Liu et al., 2024), concept learning (Huang et al., 2011), problem solving (Sung et al., 2018; Onbasi, Falyali & Ozdamli, 2021) and attitude (Onbasi, Falyali & Ozdamli, 2021).

An overview of the field of technology shows that it is not a fixed field, but rather a rapidly developing and renewing field. With this development and renewal, technology has become integrated into many fields such as tourism, health and medicine, and has brought innovation and transformation

in these fields. Another area where technology is integrated to take advantage of its advantages is education. Technology integration in education refers to utilizing technology to improve students' knowledge and skills in the teaching process (Reigeluth, 2003). Therefore, the purpose of technology integration in education is to enable learners to easily achieve curriculum goals at their own pace and not only in school but also in their comfort zone by utilizing technology in the teaching process (Ramesh, 2017; Reddy & Bubonia, 2020). When the definition and purpose of technology integration are examined, it can be said that technology integration in education can be possible by creating an intersection between technology, pedagogy and content knowledge (Dinçer & Çengel-Schoville, 2022). Therefore, for a good technology integration, teachers should utilize not only technology knowledge but also pedagogical and content knowledge (Pierson, 2001). In addition, the inclusion of technology in the general school culture can also make technology integration successful (Ross, McGraw & Burdette, 2001).

The use of technology in education has transformed education by providing methods of presenting course content to students, opportunities for students to access course content outside of class hours, and opportunities to provide students with different learning opportunities (Reddy & Bubonia, 2020). With this transformation, alternative education opportunities are provided to students (Aksu & Canturk, 2015). It encourages students to learn through educational programs that offer additional information on a subject, educational games, repetition, and award certificates (Sharma, 2024).

The use of technology in education makes teaching more accessible by creating the opportunity to participate in education from anywhere and anytime (Heemskerk et al., 2008). Utilizing technology in the education process both inside and outside the classroom will enable students to benefit from all resources and support their success (Sharma, 2024). However, considering individual differences, it should be taken into consideration that each student learns at a different pace and style and can structure the information they access differently. Therefore, in contrast to rote learning, students are provided with appropriate and meaningful education and are given the opportunity for personal learning in accordance with their own learning speed and style. At the end of this process, their progress should be monitored (Nepo, 2017; Jaiswal, 2020). At this point, the importance of providing feedback to students comes to the fore. Research findings by Wong and Yang (2017) showed that the use of technology in education has the capacity to generate immediate and asynchronous feedback. According to the feedback, the development of students' self-regulation skills can be supported (Fanshawe, Delaney & Powell, 2020). Thanks to this feedback, it is possible to say that the evaluation process will be facilitated and completed in a short time. In such a case, students can be expected to reach the effective guidance they need in a short time (Chen, Li & Huang, 2023). In addition, the feedback opportunity provided by technology in education can be expected to contribute to students' focus (Sharkawy & Meawad, 2009). It can be thought that active learning is achieved in situations where focus is more and learning is not based on memorization. Through the realization of active learning, students are provided with the opportunity to explore and learn through new ways of learning supported by constructivist learning theories (Raja & Nagasubramani, 2018). Therefore, it has improved the student's learning experience (AlShahrani, Mann, & Joy, (2017).

Students' efforts to access information in interactive online environments make it possible for them to continue their interactions, communication and collaboration with their peers and teachers outside the learning environment (Rusakova & Young, 2020; Sindi, Stanfield & Sheikh, 2021). In addition to student-teacher interaction, technology utilized in education also facilitates parents to communicate with teachers and supports cooperation between them (Sharma, 2024). Therefore, it is possible to say that with the use of technology in education, student-student, student-teacher, teacher-teacher and teacher-parent interaction increases and communication and cooperation become easier.

The effects of the integration of technology into education have been examined in many studies. Science education is one of the disciplines in which this integration is examined. Determining how technology is used in science education, which technologies are preferred, or the effects of technology on which variables are addressed can be an important road map for researchers who are conducting or will conduct studies in this field. When the literature is examined, it is seen that Wang et al. (2023) and Tosun (2024) conducted bibliometric studies on science education and presented a general evaluation of science education. However, mobile technology in science education (Crompton et al.,

2016; Bano et al., 2018; Liu et al., 2020), augmented reality (Arici et al., 2019; Irwanto, Dianawati & Lukman, 2022; Hidayat & Wardat, 2024), virtual reality (Lou et al, 2021; Lui, Not & Wong, 2023; Amarulloh & Aswie, 2024) and artificial intelligence (Jia, Sun & Looi, 2024). When the details of these studies are examined, it is understood that they are based on a particular technology. Atmaca-Aksoy (2024) conducted a bibliometric study on the use of technology in science education, but it was determined that this study was not examined specifically for a certain level of education. Based on this perspective, this study aimed to examine studies conducted over the last 25 years (2000-2024) on technologies used in primary school science education by combining bibliometric and descriptive analysis methods. To this end, the following questions were addressed:

1. How is the distribution of research on the use of technology in primary school science education according to years?
2. What is the distribution of the most common keywords in the studies on the use of technology in primary science education?
3. Do these keywords differ across years?
4. Which are the most influential countries regarding the use of technology in primary science education and what are the bibliographic links of these countries?
5. What is the distribution of keywords used by the most influential countries?
6. Who are the most influential authors of research on the use of technology in primary science education?
7. What is the distribution according to the technology used in research on the use of technology in primary science education?
8. How is the distribution according to the variables examined in the studies on the use of technology in primary school science education?

Method

Descriptive and bibliometric analysis were utilized using the PRISMA flow proposed by Moher et al. (2009) for the systematic review of research on technology-supported science teaching in primary school. Bibliometric analysis is explained as a statistical analysis of relevant publications to measure the outputs of researchers, institutions, and countries, identify national and international networks, and map the development of a particular research area (Kamran et al., 2020). Therefore, bibliometric analysis has an important place in mapping the progress and gaps in a research field as it provides researchers with a general picture of a research area (Merigó & Yang, 2017; Ülker, Ülker & Karamustafa, 2023). Descriptive analysis is generally used in processing data that does not require detailed analysis on qualitative data sets (Baltacı, 2019). The main purpose of descriptive analysis is to present the findings to the reader in a summarized form (Özen & Arslan Hendekçi, 2016). In other words, descriptive analysis is defined as a form of data analysis that helps to describe, display, or summarize the data set in a constructive way, thus allowing patterns to emerge (Lathan et al., 2023). In the study, the findings were detailed by using bibliometric analysis and descriptive analysis together. In addition, by comparing the findings of bibliometric analysis of the studies belonging to the years 2000-2024 (25 years) with the findings of descriptive analysis of the studies belonging to these years, the last 25 years have been discussed from different aspects.

Article Selection Process

Web of Science (WoS) database was utilized to access articles on the use of technology in primary school science education. WoS, which is frequently preferred in bibliometric studies, is a reliable database because it selects journals according to editorial standards and scientific impact criteria (Wang & Waltman, 2016; Chavarro, Ràfols & Tang, 2018). Another reason for choosing the WoS database is that the data to be accessed from this database is suitable for analysis in the VOSviewer program to be used for bibliometric analysis.

Using the keywords “science” and “technology” in the “basic search” section of the WoS database, 5,972,843 studies were accessed (September, 2024). When the studies were examined, it was understood that both of the keywords used in the search were very inclusive. Therefore, it was decided to determine the parameter in accordance with the inclusion criteria (being conducted on science education, using technology in teaching and covering primary school education level). The parameter to be used for searches in the WoS database was developed by the researcher as a result of the literature review. In order to ensure that studies that do not meet the inclusion criteria are eliminated during the searches, the “NOT” extension was added to the parameter in order to reach the studies that meet the inclusion criteria. For the developed parameter, the opinion of an expert conducting research on instructional technologies who had previously conducted bibliometric analysis studies was taken and the final shape of the parameter was finalized. The search parameter is as shown in Figure 1.

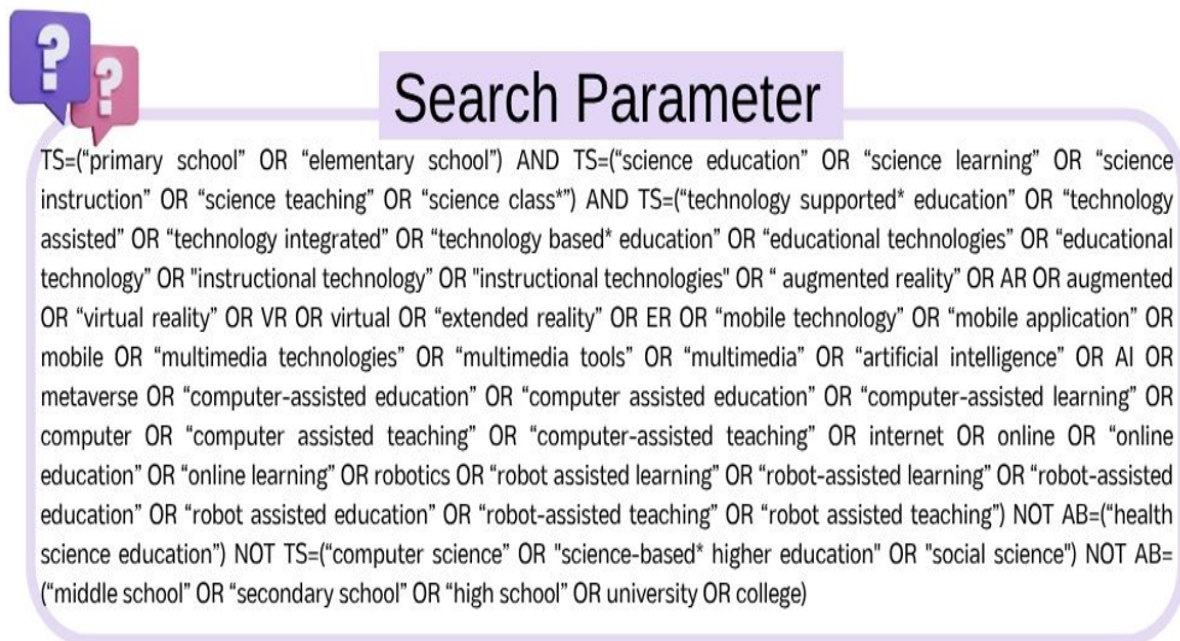


Figure 1. Search Parameter

Using the search parameter, the WoS database was searched from the “Advanced search” section and 238 studies were reached first. Afterwards, the search results were refined by using the categories in the WoS database. An examination of studies using the keywords "science" and "technology" revealed that the word "science," in particular, appears in many disciplines (health, engineering, etc.). However, the research aims to identify studies conducted in the field of education that address the use of technology in science instruction. To this end, some filtering was performed. For this refinement, the years 2000-2024 were selected first. In the search conducted using the search parameter, it was determined that the first study was published in 1995. However, since the studies published in the last 25 years (2000-2024) were examined in line with the purpose of the research, four studies published in 1995, 1998 and 1999 were excluded. In addition, Article, Early Access and Review Article were selected from the Document Type category; Education & Educational Research (E&ER) and Human Computer Interaction (HCI) categories were selected from the Citation Topics Meso category and thus 115 studies were reached (September, 2024). In order to perform the descriptive analysis, the databases were scanned again to access the full texts of the 115 studies and the descriptive analysis was performed by accessing the full texts of 107 studies. The article selection process for bibliometric analysis and descriptive analysis is presented in detail in Figure 2.

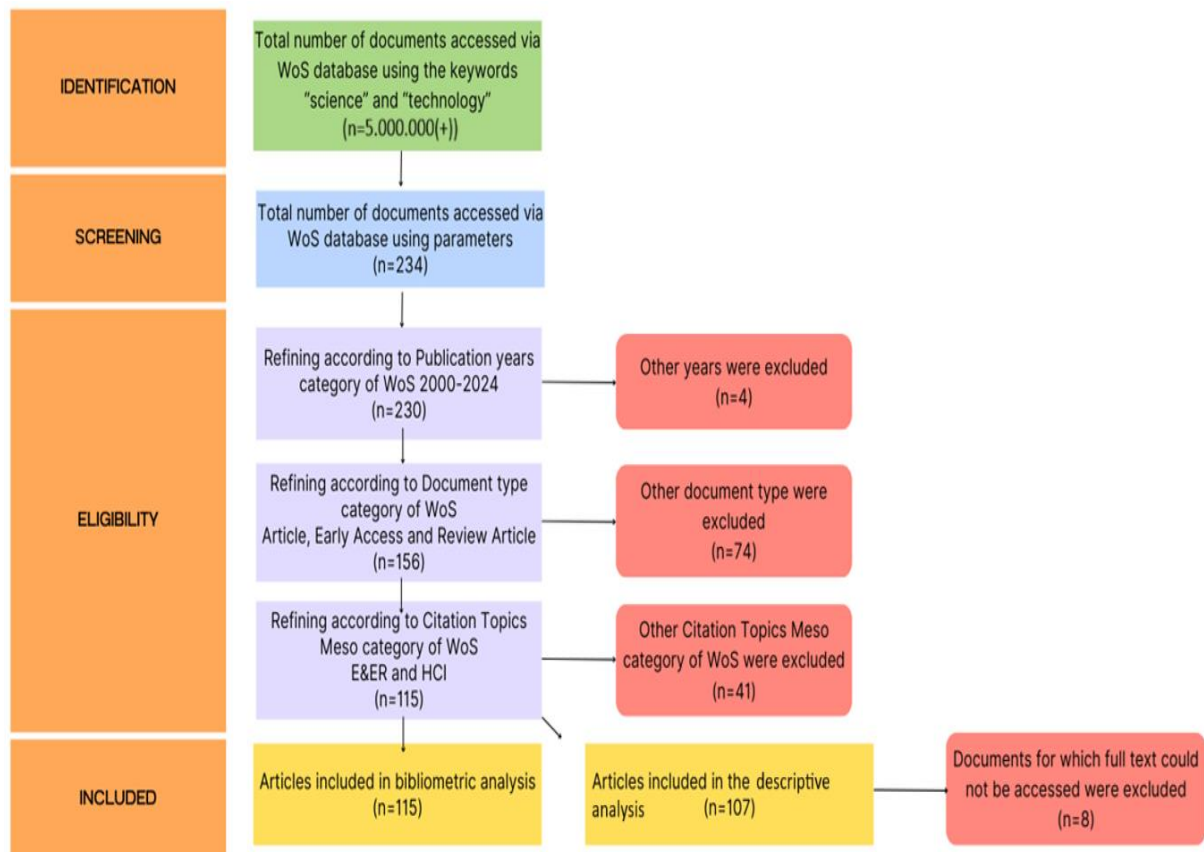


Figure 2. Article Selection Process for Bibliometric and Descriptive Analysis

Data Analysis

For bibliometric analysis, the studies accessed using the relevant parameter were saved in “Tab Delimited” format from the WoS database. While saving in this format, the record content was selected as “Full Record and Cited References”. In order to perform bibliometric analysis, this file saved using WoS was uploaded to the VOSviewer program. The VOSviewer program was preferred for bibliometric analysis due to its widespread use, ease of use and efficiency (Palabiyik & Demircan, 2021). Bibliometric network types can be examined using distance-based, graph-based and timeline-based visualization approaches (Van Eck & Waltman, 2014). In the distance-based approach, the relationship between two nodes is examined (Choudhary & Awasthi, 2018). In this study, the distance-based approach was adopted since the relationship between networks and the findings on the strength of this relationship were presented (Tosun, 2024). The VOSviewer program was chosen for this research because it adopts a distance-based visualization approach (Lima, S., & Carlos Filho, 2019; Abideen, Mohamad, & Fernando, 2021) in which the relationship between the nodes of a network is determined by the distance between them. In this bibliometric analysis, the distribution of the number of articles by year, the most frequently used keywords, the most cited authors, the most prolific authors and the distribution of authors according to their co-authorship networks, the distribution of articles by country and the bibliographic links of these countries were examined.

Among the 115 articles accessed for bibliometric analysis, 107 articles whose full text was accessed were included in the descriptive analysis in terms of the technology used and distribution according to the variables examined. In order to perform the descriptive analysis of the articles, an article review template was created using the Microsoft Excel program. With this template, it was aimed to perform coding for the descriptive information of the article (author(s), year, title and doi number), the technology used and the dependent variables analyzed. In order to classify the technologies used in the template, expert opinion was obtained from a researcher who conducts research on instructional technologies. Thus, the template to be used in descriptive analysis was finalized. The data obtained

from 107 articles accessed through WoS were coded into the template by the researcher. In order to ensure the reliability of descriptive analysis, it is possible for the same coder to record the same data set at different times (Bilgin, 2014). Based on this, the data obtained from the articles were re-coded into the template by the researcher one month later. The reliability percentage was calculated by comparing the two templates whose coding was completed. For this calculation, the formula developed by Miles and Huberman (1994), $\text{Reliability} = \frac{\text{Agreement}}{\text{Agreement} + \text{Disagreement}} \times 100$ was used. In the calculation, the reliability between the codings was determined as 97%. Considering that the reasonable reliability percentage is 80, it can be said that the coding made by the researcher is reliable (Bradley, Curry & Devers, 2007). Frequency and percentage values for the situations (technologies and variables) examined in the descriptive analysis were presented using tables or graphs.

Findings

Distribution of Studies by Years

WoS filtering option was used to determine the distribution of articles by years and the findings are presented in Figure 3.

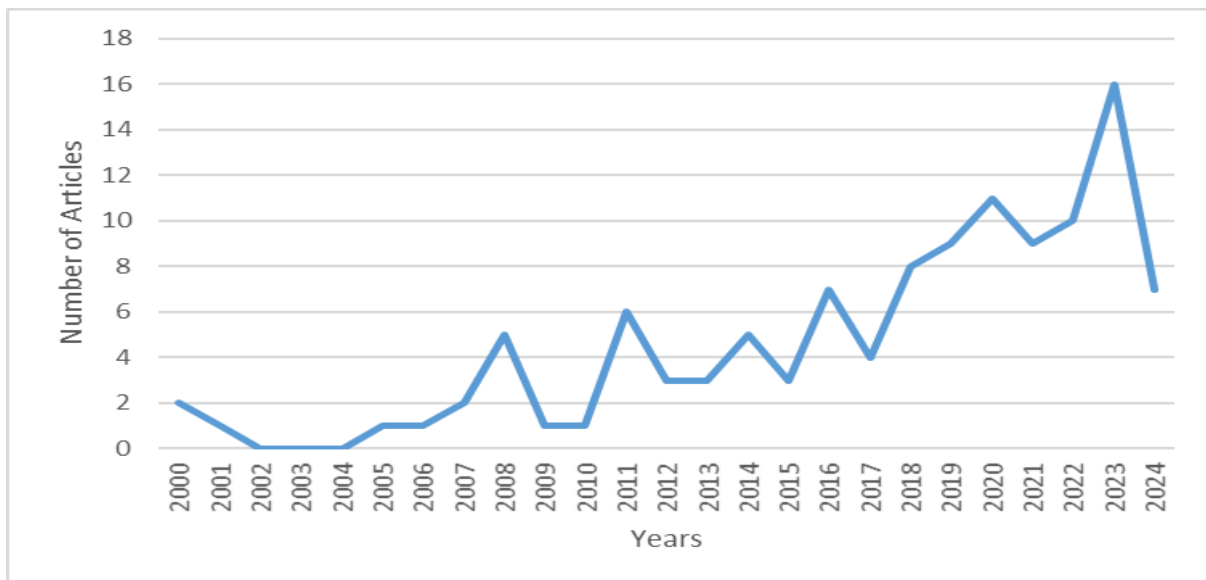


Figure 3. Distribution of Articles by Years

When Figure 3 is analyzed, it is seen that research on the use of technology in primary school science education has an unstable increase between 2000 and 2024. While there were no studies on the use of technology in primary school science education in 2002, 2003 and 2004, the number of related studies ($f=16$) reached the highest level in 2023. When the year 2024 is analyzed, it is observed that the highest decrease is observed in this year ($f=7$). However, it can be said that the reason for this decrease is that the bibliometric analysis was carried out in September 2024 and did not include articles published at the end of 2024.

Distribution of Keywords

In order to create a map based on the text data of the most commonly used keywords in the relevant articles, “co-occurrence” was determined as the analysis type and “author keywords” as the analysis unit in the VOSviewer program. While the minimum number of repetitions of a keyword was determined as 5, 9 out of 361 keywords met this threshold. Thus, the relational network map of the keywords was created and presented in Figure 4. In addition, the findings regarding the keywords with total link strength are given in Figure 5.

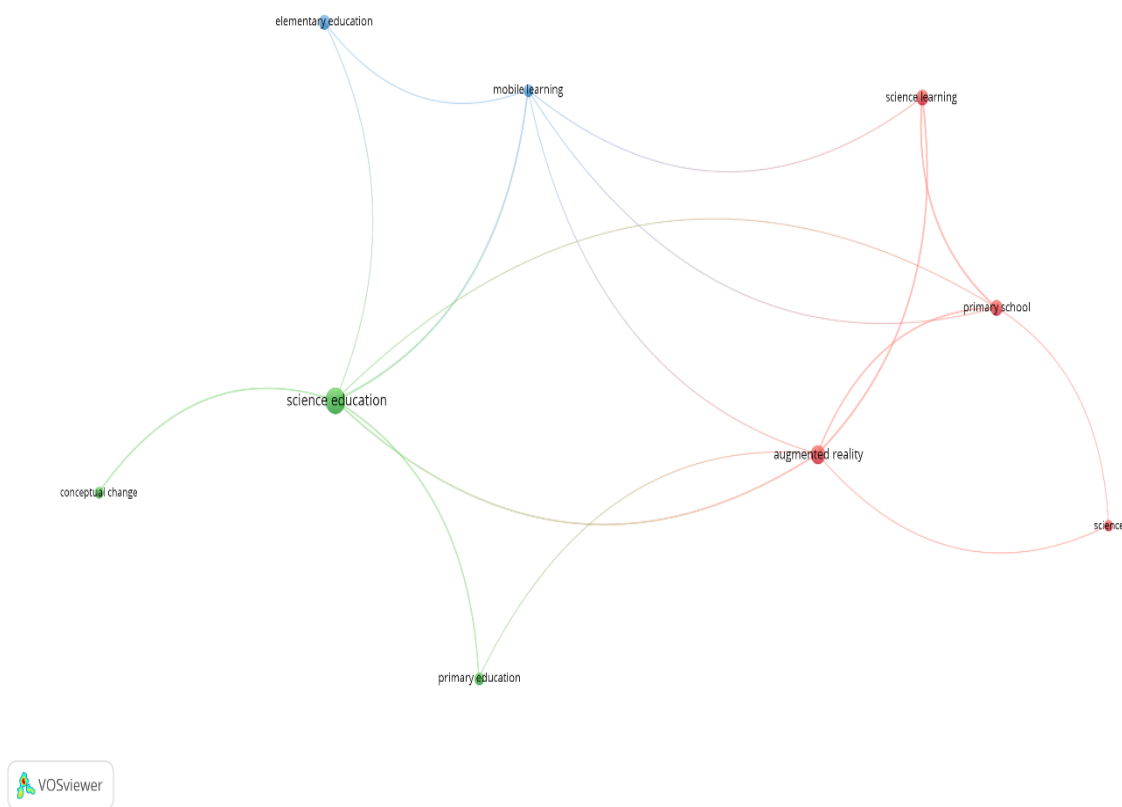


Figure 4. Relational Network Map of Keywords

Selected	Keyword	Occurrences	Total link strength
☒	science education	23	11
☒	augmented reality	12	10
☒	primary school	9	8
☒	mobile learning	6	7
☒	science learning	9	7
☒	primary education	6	3
☒	conceptual change	5	2
☒	elementary education	7	2
☒	science	5	2

Figure 5. Findings on Occurrences and Total Link Strength of Keywords

When Figure 4 is examined, it is seen that three different clusters are formed, with the keywords “science education” in the green cluster, “mobile learning” in the blue cluster and finally “augmented

reality” in the red cluster. The most frequently used keyword in the articles with the highest total link strength was “science education” (O=23; TLS=11), followed by “augmented reality” (O=12; TLS=10), “primary school” (O=9; TLS=8) and “science learning” (O=9; TLS=7) (Figure 5). The keyword “mobile learning” was the keyword with the highest rate of association with the keyword “science education”. The keyword “augmented reality” was most highly related to the keyword “science learning”.

The distribution of keywords by years is shown in Figure 6.

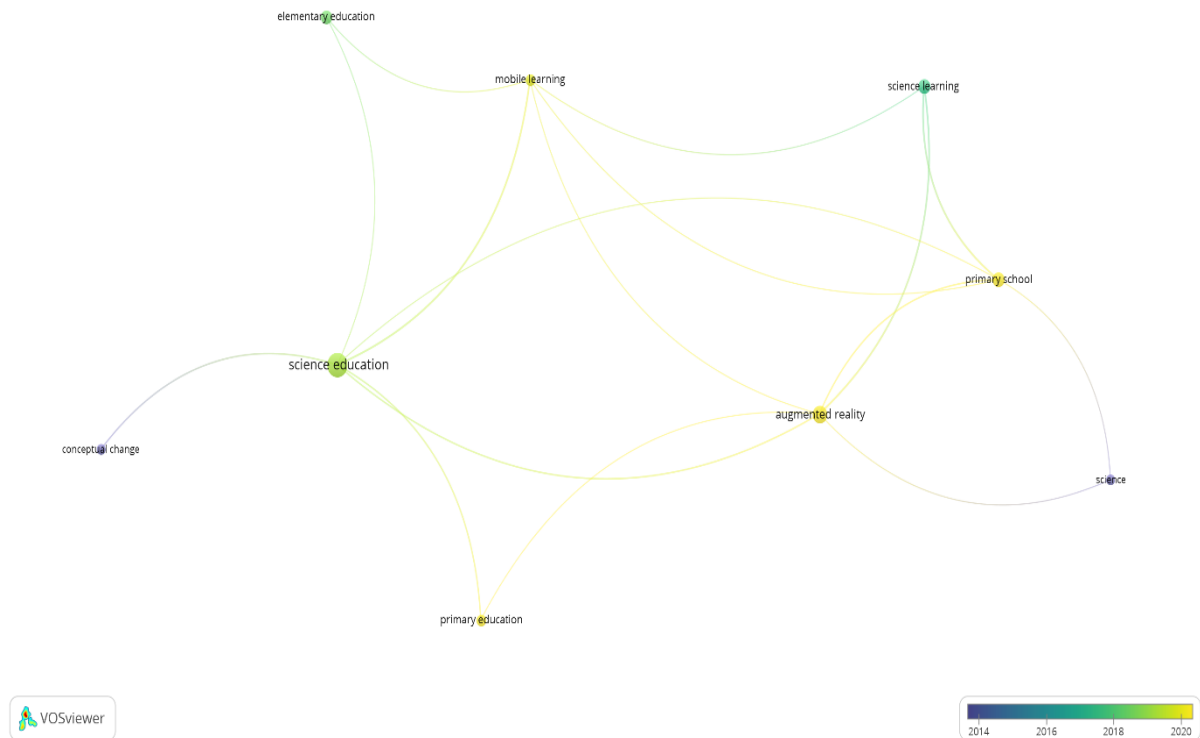


Figure 6. Relational Network Map of Keywords by Years

Figure 6 shows that research on “augmented reality” and “mobile learning” in primary school science education has increased in recent years.

Most Productive Countries and Their Bibliographic Links

The distribution of research on the use of technology in primary school science education by country is given in Table 1 and it is aimed to identify the most productive ones from these countries. For this, WoS filtering options were utilized.

Table 1.

Distribution of Studies according to Countries

Countries	<i>f</i>	%	Countries	<i>f</i>	%
Taiwan	24	21	England	5	4,3
People R China	18	16	Netherlands	5	4,3
USA	14	12	Australia	4	3,5
Turkey	9	7,8	Malaysia	4	3,5
Cyprus	6	5,2	Slovenia	4	3,5
Finland	6	5,2	Greece	3	2,6
Indonesia	6	5,2	Portugal	3	2,6
			Singapore	3	2,6

According to Table 1, it is seen that the most research on the use of technology in primary school science education was conducted in Taiwan ($f=24$, 21%). This country is followed by People R China ($f=16$, 16%), USA ($f=14$, 12%) and Turkey ($f=9$, 7.8%). Therefore, it can be said that these countries are the most productive countries in terms of research on the use of technology in primary school science education. In order to analyze the most commonly used keywords in the related studies of these countries, the WoS filtering option was used and “co-occurrence” was selected as the type of analysis and “author keywords” was selected as the unit of analysis in the VOSviewer program. The minimum number of repetitions of the keyword for each country was set as 2. The distribution created according to the data obtained is presented in Figure 7.

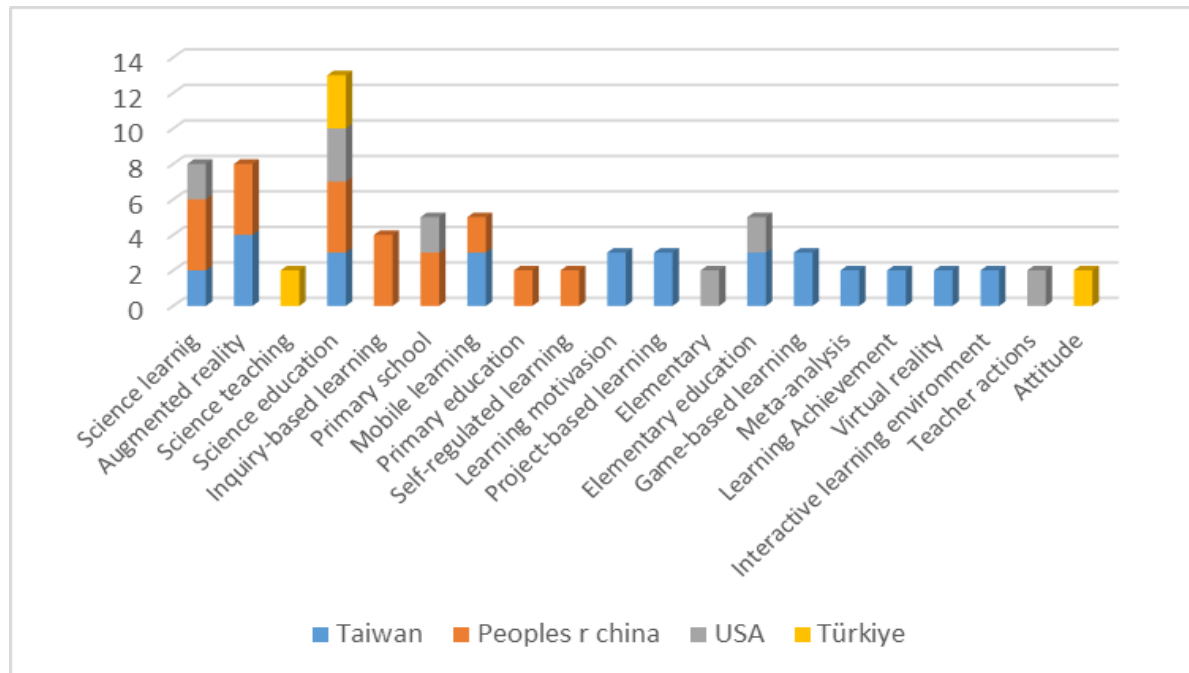


Figure 7. Keyword Distribution according to The Most Productive Countries

When Figure 7 is analyzed, it is seen that twenty different keywords were formed in the studies of the most productive countries. It is seen that the keyword “science education” is used by all four most productive countries. The keyword “science learning” was used only by Taiwan, People r China and USA, while the keyword “science teaching” was used only by Turkey. The keywords “augmented reality” and “mobile learning” were observed only in Taiwan and People r China. The keyword “primary school” was found only in People r China and USA, while the keyword “elementary education” was found only in Taiwan and USA. The keywords “science education” and “attitude” were used only in Turkey; the keywords “inquiry-based learning”, “primary education” and “self-regulated learning” were used only in People r China; the keywords “learning motivation”, “project-based learning”, “game-based learning”, “meta-analysis”, “learning achievement”, “virtual reality” and “interactive learning environment” were used only in Taiwan; and finally the keywords “elementary” and “teacher actions” were used only in USA. In addition, the keywords “science learning” and “science teaching” were also used. The keywords used for technology in the research of the most productive countries are “augmented reality” and “mobile learning”.

In order to create a network map of the countries of the articles included in the bibliometric analysis and to determine the total link strength, “bibliographic coupling” was determined as the analysis type and “countries” as the unit of analysis. When the minimum number of articles of the countries was set as 1, it was determined that 31 countries had articles on the relevant topic. In addition, when the minimum number of citations was added to the analysis as 1, it was determined that 27 countries met this condition. Thus, a network map of the countries is created and shown in Figure 8 and the results for the countries according to total connection strength are shown in Figure 9.

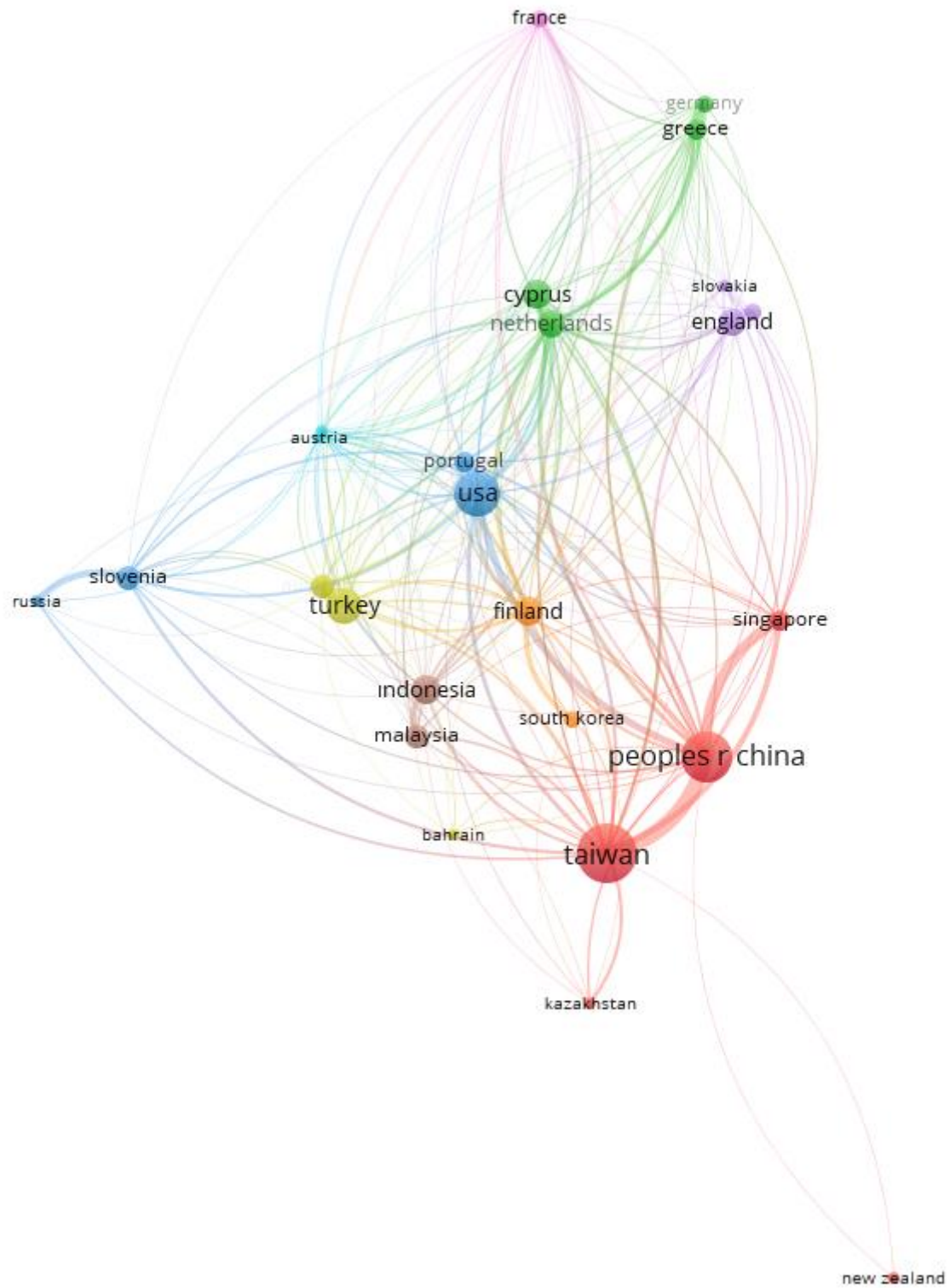


Figure 8. Relational Network Map of Countries

Selected	Country	Documents	Citations	Total link strength ✓
☒	peoples r china	18	253	1104
☒	taiwan	24	1423	862
☒	netherlands	5	155	488
☒	singapore	3	3	396
☒	usa	14	275	363
☒	finland	6	332	297
☒	slovenia	4	58	208
☒	cyprus	6	105	195
☒	germany	2	33	189
☒	greece	3	16	189
☒	indonesia	6	19	186
☒	turkey	9	116	183
☒	australia	4	112	182
☒	portugal	3	12	156
☒	austria	1	3	145
☒	serbia	1	3	145
☒	england	5	46	128
☒	france	2	2	123
☒	italy	1	1	123
☒	malaysia	4	17	122
☒	ruusia	1	8	115
☒	south korea	2	65	71
☒	israel	2	5	67
☒	slovakia	1	11	39
☒	kazakhstan	1	6	37
☒	bahrain	1	3	19
☒	new zealand	1	1	2

Figure 9. Findings on Total Link Strength, Document and Citations of Countries

When the network map presented in Figure 8 is analyzed, it is seen that nine clusters are formed. Within these clusters, red, blue and green clusters stand out. It is seen that the country “People r China” in the red cluster has the highest value in terms of total connection strength (TLS=1104). The link between “People r China” and “Taiwan” is the strongest link on the map. However, “People r China” also has strong connections with “Singapore” and “USA” respectively. On the other hand, despite having the highest number of publications (D=24) and citations (C=1423), “Taiwan” ranks second in terms of total link strength (TLS=862). When the green cluster is analyzed, it is seen that “Netherlands” (D=5; C=155; TLS=488) is dominant. This country has the strongest connections with “Germany”, “Greece” and “Finland”. Finally, it is seen that “USA” stands out in the blue cluster within the dominant clusters in the network map (D=14; C=275; TLS=363). In addition to “People r China”, this country also has strong links with “Netherlands” and “Taiwan”.

Most Prolific Authors

In order to create a network map showing the most productive authors and the relationship between these authors in research on the use of technology in primary school science education, “citation” was determined as the type of analysis and “authors” as the unit of analysis. Articles with 25 or more authors were not included in the analysis due to their negligible contributions. When the authors with at least one article in the VOSviewer program were analyzed, it was determined that 344 authors had articles. However, since it was aimed to determine the most influential authors and the connection between them instead of including all authors in the network map, the minimum number of articles of the authors was determined as 2 and the minimum number of citations as 10. In line with these values, it was determined that 21 out of 344 authors met the relevant threshold. Thus, the network map for the link strength among authors is shown in Figure 10 and the findings regarding the article, citation and total link strength are given in Figure 11.

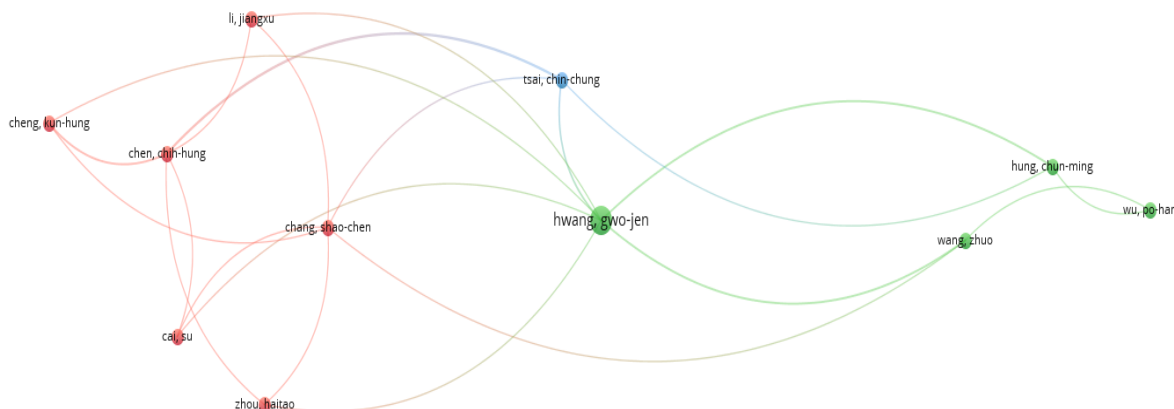


Figure 10. Network Map for Authors

Selected	Author	Documents	Citations	Total link strength ▼
☒	hwang, gwo-jen	6	611	10
☒	chen, chih-hung	2	139	8
☒	tsai, chin-chung	2	73	7
☒	chang, shao-chen	2	219	6
☒	cheng, kun-hung	2	58	4
☒	hung, chun-ming	2	177	4
☒	jaakkola, tomi	3	160	4
☒	veermans, koen	2	140	4
☒	wang, zhao	2	71	4
☒	cai, su	2	11	3
☒	li, jiangxu	2	11	3
☒	zhou, haitao	2	11	3
☒	de jong, ton	2	34	2
☒	wu, po-han	2	238	2
☒	angeli, charoula	2	48	0
☒	dinevski, dejan	2	39	0
☒	herga, natasa rizman	2	39	0
☒	pedro, luis	2	12	0
☒	tavares, rita	2	12	0
☒	vieira, rui marques	2	12	0
☒	zacharia, zacharias c.	2	42	0

Figure 11. Most Productive Researchers

Figure 10 shows that there are three clusters (green, red and blue). It is seen that “Hwang, Gwo-Jen” in the green cluster is the most productive author in terms of number of articles, total link strength and number of citations (TLS=10; D=6; C=611). The most cited studies of this author are “an online game approach for improving students’ learning performance” (Hwang, Wu & Chen, 2012), “an augmented reality-based reverse learning guidance approach for students’ scientific project performance” (Chang & Hwang, 2018) and “a project-based digital storytelling approach for improving students’ learning performance” (Hung, Hwang & Huang, 2012). This author was also found to have a higher connection strength with authors such as “Wang, Zhuo”, “Hung, Chun-Ming” and “Tsai, Chin-Chung” than other authors. “Chen, Chih-Hung” is the author with the highest link strength in the red cluster (TLS=8; D=2; C=139). The most cited study of this author is his research on “an augmented reality-based learning approach to improve students’ science reading performance” (Lai, Chen & Lee, 2019). The link strength of this author with “Tsai, Chin-Chung” is higher than the other authors.

As a result of the detailed analysis of the keywords used by the five most productive researchers in the research on the use of technology in primary science education, it was determined that the keywords “learning motivation”, “mobile learning”, “game-based learning”, “science learning”, “interactive learning environments” and “augmented and virtual reality” came to the fore. Since the most

productive authors are also the most cited authors, it may be possible to comment on the trend of research on the use of technology in primary school science education. Accordingly, it can be said that the effect of mobile learning, game-based learning, augmented and virtual reality is seen in science teaching.

Distribution according to The Technologies Used in The Studies

The distribution of the technologies utilized in the studies on the use of technology in primary school science education and whose effects on the variable were examined is given in Table 2.

Table 2.

Distribution of Technologies Used in the Studies

Technologies Used in Research	<i>f</i>	%	Technologies Used in Research	<i>f</i>	%
Multimedia technologies	27	23,5	Virtual Labs/Experiments	6	5,2
Technology-supported teaching	22	19,1	Artificial intelligence/Coding	5	4,3
Augmented reality	15	13	Videos	2	1,7
Online environments	11	9,57	Digital story	1	0,9
Games	9	7,83	Internet of things	1	0,9
Mobile technologies/applications	8	6,96	Mixed reality	1	0,9
Virtual reality	7	6,09			

As seen in Table 2, it was determined that thirteen different types of technology were utilized in primary school science education research. “Multimedia technologies” ($f=27$, 23.5%) is the most utilized of these technology types. This is followed by “Technology-supported teaching” ($f=22$, 19.1%), “Augmented reality” ($f=15$, 13%) and “Online environments” ($f=11$, 9.57%). The least utilized technologies in the studies were “Digital story”, “Internet of things” and “Mixed reality” ($f=1$ for all, 0.9%).

Distribution according to The Variables Analyzed in The Studies

The frequency and percentage distributions of the variables examined in the studies on the use of technology in primary school science education are presented in Table 3.

Table 3.

Distribution of Variables Analyzed in the Studies

Variables	<i>f</i>	%	Variables	<i>f</i>	%
Success/Learning	34	19	Self-efficacy	4	2,3
Opinion/Experience	22	13	Perception	4	2,3
Motivation	18	10	Creative Writing/Thinking	3	1,7
Concept learning	10	5,7	Interest	3	1,7
Information	10	5,7	Pedagogical change/development	3	1,7
Critical thinking/problem solving	9	5,1	Quality of speech/drawing	2	1,1
Questioning/Judgement	8	4,5	Technology usage/acceptance	2	1,1
Performance	7	4	Scientific process skills	1	0,6
Conceptual understanding	6	3,4	21st century skills	1	0,6
Cognitive load	6	3,4	Behavioral intention towards AR usage	1	0,6
Attitude	5	2,8	Misconception	1	0,6
Learning retention/transfer	5	2,8	Anxiety	1	0,6
Epistemological belief	5	2,8	Participation	1	0,6
Flow State/ Flow Experience	4	2,3			

As seen in Table 3, twenty-seven different variables were examined in the studies on the use of technology in primary school science education. Among these variables, “Success/Learning” ($f=34$, 19%) was the most examined variable. This was followed by “Opinion/Experience” ($f=22$, 13%) and “Motivation” ($f=18$, 10%). “Scientific process skills”, ‘21st century skills’, ‘Behavioral intention

towards AR usage', 'Misconception', 'Anxiety', and 'Participation' ($f=1$, 0.6% for all) were the variables that were the least examined.

Discussion, Conclusion, and Suggestions

When the distribution of the studies according to years is analyzed, it is noteworthy that the number of studies is unstable. However, it was determined that the number of studies on the use of technology in science teaching has increased remarkably in the last five years compared to the previous years. The first reason for this situation can be seen as the fact that the rapid and remarkable progress in technology has attracted the attention of not only individuals who follow technological developments but also teachers. Because teachers' acceptance of technology is seen as an important factor for the effective use of these technologies in educational environments (Kumar, Rose & D'Silva, 2008). However, it has been determined that teachers cannot integrate the use of technology into educational environments (Asan, 2003). Because teachers did not have the necessary tools and knowledge to ensure technology integration (Sipilä, 2014). In a study conducted in 2016, it was determined that teachers needed not only the necessary knowledge but also the skills to use this knowledge and the right attitudes (Spiteri & Chang Rundgren, 2020). When the dates of these studies are examined, it is seen that they were conducted before the Covid-19 pandemic. During the Covid-19 pandemic, it has become imperative to utilize technology not only by teachers but also by students and even parents in order to maximize teaching. Considering that there is a direct proportion between the frequency of using technology and the perspectives towards technology (Kaplan-Rakowski et al., 2023), the Covid-19 process can be seen as the second reason for this finding obtained in this study. Because the increased use of technology in the Covid-19 process (Winter et al., 2021; Moorhouse, 2023) may have positively affected teachers' knowledge, attitudes and experiences towards technology.

In the bibliometric analysis of keywords, it was determined that the keywords "science education", "mobile learning" and "augmented reality" were dominant in 3 different clusters and the linking power of the keywords "science education", "augmented reality", "primary school" and "science learning" was the highest. It can be said that the keywords "science education", "primary school" and "science learning" come to the forefront since the research is based on "science teaching in primary school". As another result of the bibliometric analysis, the keywords "augmented reality" and "mobile learning" stand out. When the relational network map findings of the keywords according to years are analyzed, it is seen that "augmented reality" and "mobile learning" have come to the forefront in recent years. However, as a result of the descriptive analysis, it was determined that "Multimedia technologies", "Technology-supported teaching" and "Augmented reality" technologies were the most used technologies in the last 25 years. Therefore, based on these two findings, it can be said that "Multimedia technologies" and "Technology-supported teaching" have been used the most in the last 25 years, but "augmented reality" and "mobile learning" have replaced them in recent years. Arıcı et al. (2019), who conducted a bibliometric analysis study on augmented reality in science education, reached similar results and explained this situation with the ease of access to mobile technologies. However, in addition to ease of access, the advantages of mobile learning such as providing new ways of learning such as simulation and animation, enhancing learning, organizing learning, interaction and collaboration, which were compiled by Criollo-C, Luján-Mora & Jaramillo-Alcázar (2018), may have brought mobile learning to the forefront in recent years.

In the country-based analysis, it was determined that the 4 most productive countries were Taiwan, People R China, USA and Turkey, respectively. However, when analyzed in terms of connection days, it was determined that People R China ranked first and Taiwan ranked second. When the countries were analyzed in terms of keywords, it was seen that the keyword "augmented reality" appeared predominantly in these two countries. We would like to remind that this keyword is among the most used keywords and technologies in primary school science education. It was also found that these two countries have the strongest connection between countries. Based on all these, it is possible to say that Taiwan and People R China have a strong, pioneering and decisive influence on the use of technology in primary school science education. When the information in WoS of the most prolific authors, Hwang, Gwo-Jen and Chen, Chih-Hung, was examined, it was seen that they conducted their studies

in an organization in Taiwan. Therefore, it is seen that the country where the researchers' organizations are located affects their productivity and connectivity. In the bibliometric analysis on the use of robots in science education conducted by Chiu, Hwang & Tu (2024), it was determined that Taiwan and People R China countries focused on this field between 2016-2020. When both research findings are combined, it can be said that the research trend in Taiwan and People R China, which started between 2016-2020, has increased rapidly in the last 4 years. In another bibliometric-based study on digital game-based learning, it was determined that Taiwan was the country with the highest contribution and Hwang, Gwo-Jen was the most influential author (Chen et al., 2022). The result of the bibliometric analysis conducted by Karakus, Ersozlu and Clark (2019) on augmented reality in education also showed that Taiwan is among the most influential countries. According to the results of this research, it can be said that Taiwan's educational environments are supported more than other countries for utilizing technology in educational environments. In the study by Chou and Ching (2012), it was stated that education in Taiwan is intertwined with information communication technologies and that the Internet, electronic boards, computers and televisions have entered Taiwanese classrooms. Therefore, it can be said that technology integration into education in Taiwan was completed many years ago. Wu et al. (2013) found that specific instructional technologies such as online collaborative writing were adopted more than general purpose technologies such as PowerPoint. based on this result, it can be said that educational technologies are followed in this country and education is shaped in line with these changes and developments. Based on this, it can be suggested that education policy makers in other countries should examine the use of technology in Taiwanese schools and classrooms and transfer these practices to schools and classrooms in their own countries.

It was determined that “Success/Learning” was frequently addressed as a variable in the studies, followed by “Opinion/Experience”, “Motivation”, “Concept learning” and “Information” variables. Therefore, it can be thought that the effect of technology use on these variables is a matter of curiosity for researchers. Among the reasons for the prominence of these variables, the most basic purpose of science education can be seen. Accordingly, science education is related to providing basic knowledge about the environment and nature and introducing scientific knowledge and principles (Soslul, 2014; Önal & Saribaş, 2019). However, when we expand the purpose of science education, it is possible to see that this explanation is extremely limited. Therefore, it can be thought that the variables of these studies are mostly handled from this limited framework. Because science education does not only deal with gaining knowledge. It should be taken into account that science teaching is generally a matter of understanding a way of thinking that will complement students' existing ways of thinking and is not actually about convincing students of the truth of any particular scientific explanation (Taber, 2017). Based on this idea, science education should also aim to support students' skills such as discovering ways to access scientific knowledge, questioning the information they have accessed, generating scientific arguments, evaluating the arguments generated, making predictions based on data, hypothesizing/testing, scientific literacy and problem solving. Based on this, addressing scientific process skills, which have an important place in 21st century skills and science education, in future studies can fill this gap in the field. In addition, students' argument quality, discussion skills and metacognitive skills can be seen as important variables that should be examined in the use of technology in education.

Limitations and Suggestions for Future Research

While significant findings were obtained in the study, it can be said that there are also some limitations. The research data is limited to the Web of Science database. Future research could utilize other databases (such as Scopus or ERIC) that can provide the necessary data for bibliometric analysis. This study included article, early access, and review article studies published between 2000 and 2024. Further studies may expand the time period or include conference proceedings. During the descriptive analysis process of this study, data were coded by a single coder at different time intervals. In future studies, the inclusion of a second coder could be considered to increase reliability and reduce interpretation bias. This study examined data from studies on the use of technology in elementary school science education. However, similar studies can be conducted in other disciplines and at other levels of instruction. The research data is limited to the presented search parameter. However, with advancements in technology, this search parameter can be expanded by adding different keywords.

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