

Review Article

Cite this article: Barak, H. & Yirci, R. (2025). A Bibliometric Analysis of Teachers' Technological Leadership: What Stands Out in the Studies?. *Educational Process: International Journal*, 17, e2025393. <https://doi.org/10.22521/edupij.2025.17.393>

Received April 24, 2025

Accepted July 30, 2025

Published Online August 21, 2025

Keywords: Technology, leadership, technology integration, teacher, technology in education

Author for correspondence:

Hilal Barak

✉ hilalbrk4@gmail.com

✉ Teacher, Ministry of National Education, Directorate of Kahramanmaraş, Türkiye.

A Bibliometric Analysis of Teachers' Technological Leadership: What Stands out in the Studies?

Hilal Barak , Ramazan Yirci 

Abstract

Background/purpose. The introduction of learning management systems, interactive whiteboards, educational games, and artificial intelligence-supported educational technologies highlights the importance of technological leadership as a top competency for teachers. Since effective technological leadership requires a high level of education, numerous studies have been conducted on this subject, and an extensive knowledge base has been formed. The research was carried out in order to examine the knowledge base formed in this field holistically, to determine the current situation and to provide a guiding study for future studies.

Materials/methods. A descriptive and bibliographic analysis of 400 articles and early access articles selected from the Web of Science database was conducted using VOSviewer software.

Results. According to the findings, the most influential author is Johan Van Braak and the most influential journal is 'Computer & Education'. The most influential country was determined to be the USA. It was determined that the most used keywords in the study were leadership and technology integration. It was concluded that the top-ranked studies focused on teachers' efforts to integrate technology into education. There are few studies originating from Turkey, and it is predicted that the number of studies will increase in the coming periods, thanks to technological advancements in education.

Conclusion. The study analysed publications, authors, countries, journals, source types, citation counts, and collaborations that are leading in the field of teacher technological leadership. A framework has been established for many components, such as current research topics and future research trends. At this point, this study will reflect trends and current issues related to teachers' technological leadership and will play an active role in conducting different studies in this field.



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1. Introduction

The age we live in has increased the need for individuals who can access information through different channels, approach critically and produce creative ideas. In order to raise individuals with these requirements, changes should be made in educational environments. By supporting educational environments with technology, we can raise students who learn to learn, think critically, and have problem-solving skills (Atav et al., 2006, pp. 38–39). Students should be able to follow their learning processes and teachers should be able to lead them in this regard. This leadership model is a departure from traditional leadership, focusing on accessing information rather than the position of the person who presents it, and enabling the student to discover. Today, this is called technological leadership. It is important for teachers to be individuals who can absorb and actively use technology in the 21st century.

As a society, the changing labour force branches in the process of technological transformation require the new generation to be individuals who produce rather than consume information. Individuals should use technology consciously and wisely and should be able to direct their own learning processes when necessary. In addition, it has been determined as a result of studies and reports by national and international organisations that they should have some skills such as information literacy, data literacy, and the ability to use artificial intelligence technologies. Teachers have a great responsibility in providing these skills to students in schools and maximising the potential of individuals. As a result of this, the Directorate of Teacher Training and Development of the Ministry of National Education added the article of using information and communication technologies effectively to the general qualifications for the teaching profession, which was published in 2006 and updated in 2017. Likewise, according to the report published by the European Organisation for Economic Cooperation (OECD) in 2019, it is stated that teachers' ability to use innovative technological tools has an important role in developing the new generation skills that students need, and that it supports the learning of students who cannot learn with traditional learning methods and need more time and different tools. Teachers' technological competences have a significant effect on the students' meeting with new generation learning tools and their use of these tools. When the education systems of the countries are examined, it is seen that they endeavour to bring international standards and integrate these standards into their systems. However, it is seen in the analysis conducted by OECD (2016) that this effort is not at a sufficient level. According to the analysis, although countries make large investments in information and communication technologies, they still state that technology adaptation has not been achieved. Teachers have the most important role here. According to the guide published by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), teachers should be pioneers in information and communication technologies. Brooks (2013) states that, in addition to innovative steps, the concrete support of individuals in education is important for technology integration. It is seen that the Ministry of National Education (2006) is based on international standards while determining teacher competencies. It is emphasised that teachers should use technology effectively in the education-training process, guide students in this regard, and equip them with 21st-century skills.

In light of these technological developments, scientists have conducted extensive research on technological leadership. These developments have also increased co-operation in parallel with the ease of communication channels between scientists. In the first quarter of the 21st century, co-authorship or joint institutional studies are frequently encountered. Due to the importance of the studies, bibliometric studies are needed to reveal the intellectual structure of the knowledge base on teachers' technological leadership in the literature. As a result of these studies, the body of knowledge in the field is analysed, and research trends are revealed. Studies are analysed according to certain characteristics (citations, keywords, influential author names, etc.), and various data are

obtained. These data provide us with the opportunity to evaluate the performance of authors, countries, and institutions. According to the evaluation result obtained, the data can be mapped and visualised statistically. In this way, bibliometrics enables the quantification of the publications examined and the identification of trends in the field (Kasemodel et al., 2016; Köseoğlu, 2016). Citation analysis in bibliometric studies provides not only the quantification of publications but also the determination of the quality of publications. Considering these important benefits of bibliometric analysis, this study aims to reveal the development and intellectual structure of teachers' technological leadership research as a result of descriptive and bibliometric analyses. In this context, the study aims to answer the following research questions.

1. How are the document types and publication years of the publications on teachers' technological leadership distributed?
2. Which authors, journals, and countries are the most influential in the data obtained from the teachers' technological leadership knowledge base?
3. What is the network structure of co-authorships of publications on teachers' technological leadership?
4. What is the network structure of the common keywords of the publications on teachers' technological leadership?

2. Literature Review

2.1. Leadership

The concept of leadership has emerged in ancient times, has maintained its topicality, and has been a subject that has attracted the attention of scientists (Arslanoğlu, 2016, p. 24). The word 'leader', derived from the Latin word 'lira', means a person who leads, pioneers, and is aware of the group's wishes and needs in advance. Leadership, on the other hand, is understood as the art of mobilising, motivating, and coordinating the people in the organisation in order for the group to achieve its goals. Although there are many definitions of leadership in the literature, one common quality is the ability to influence the group that comes together to realise a goal (Davies, Hides, and Casey 2001, 1027). In addition, it has been stated that people who have the ability to make effective decisions, to direct and manage the group, and to gather the group around common goals can be effective leaders (Burns, 1978; Stogdill, 1974; Yukl 1981, 1994). People have always needed to act in a group and with a group, even to achieve some personal goals. For this reason, people need to be aware of their wants and needs, and they need the help of a leader to realise them. Today, this situation has become even more important.

The transformation of the world into a large market with globalisation has strengthened the phenomenon of competition in organisations. In addition, developments in technology and socio-economic and socio-cultural changes have also played an important role in strengthening this competition. Depending on all these developments, it would not be wrong to say that leadership perception should adapt to this new process. Leaders who can recognise and adapt to changes will be more successful (Paksoy, 2010, p. 26). The leader should adopt different cultural characteristics and should be able to have an impact on the mindsets, attitudes, and behaviours of individuals in the organisation (Çalışkan, 2010, p. 271). For these reasons, recent studies on leadership have focused on managing change and cultural development of organisations (Köseoğlu, 2019, pp. 43–44). As a result, it is predicted that new current formations have emerged in the field of leadership with globalisation and that future studies will progress in this direction.

In the 21st century, leadership is one of the most studied fields in social sciences. Most studies are in the fields of education, management and business administration. As a result of these

studies, many definitions of leadership have entered the literature. Since leadership is a concept that can be analysed in different ways with different perspectives, its definitions also vary (Şişman, 2018, p. 1; Karakose & Tulubas, 2025).

2.1.1. Technological Leadership

As in every community, people with leadership qualities have always been prominent in our educational institutions. In our educational institutions, students, teachers, and school administrators are together. There is a need for leading individuals who can bring our schools to the targeted success, meet the expectations, and be equipped with today's skills. One of the most important skills that leaders should have is technological leadership skills.

Toduk & Gande (2016) define technological leadership as creativity, having in-depth knowledge, strong networking through collaboration, and having a strong vision. Technological leaders are individuals who are curious, think critically, have a universal vision and collaborate. Petry (2018) evaluates technological leadership not only as a feature of mastering digital, but also within the framework of the sense of trust created by people who adopt the principle of open, agile, and participatory approaches. Today, the acceleration of technological developments and the continuity of this situation show that leaders should care about their followers' sense of trust (Çelebi, 2021). Because it is possible to say that organisations with individuals who trust their leaders at the point of change and transformation will be more successful, at this point, it is stated that technological leadership requires different equipment compared to other types of leadership. In addition to the necessary trust environment, technical knowledge and skill mastery are important for these leaders.

Technological leadership is the use of information technology resources by teachers and students to achieve high success in the process of educational activities (Durnalı, 2019; Karakose et al., 2023). Durnalı (2019) defined technological leaders as people who can construct education and technology intertwined, use school resources at the point of providing technology, benefit from educational technologies in the professional development process, and guide students in the use of technology.

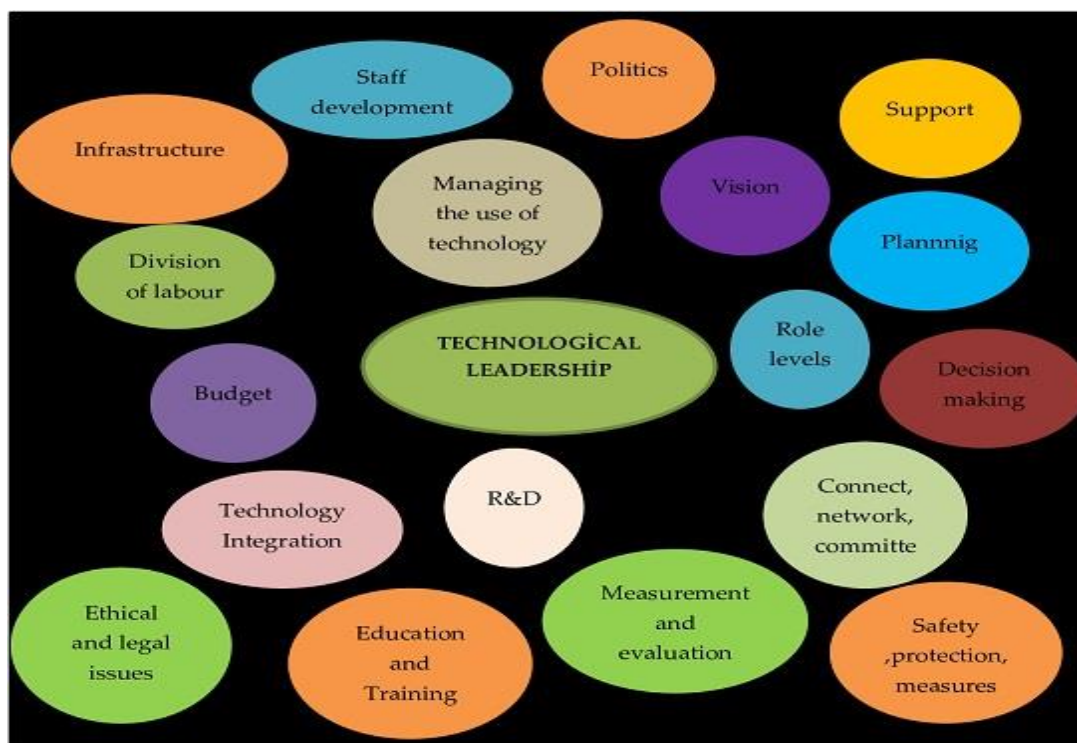


Figure 1. Technology Leadership Model, Durnalı (2018)

By examining the research on technological leadership, the dimensions, roles, and models were compared in terms of their similarities and differences, and visualised by Durnalı (2018) and shown in Figure 1. Durnalı (2018) created keywords in this visualisation. In the visual, it is seen that technological leadership has many dimensions. Although it is difficult to say that these dimensions and models overlap with the Turkish education system in every sense, it is possible to say that they have similar aspects. Measurement and evaluation centres established in the provinces and R&D units within the national education directorates can be given as examples of similar aspects.

2.1.1.1. The Importance of Technological Leadership for Education

Many innovations and changes have occurred in history from the early ages to the present day. In this process, the development of computers and the comprehension of information that cannot fit into human life, and being an effective tool that helps the human brain, is the biggest development. Thanks to computers, human beings not only produce information fast, but also exceed their capacity, and their memory has reached astonishing dimensions (Yilmazel, 2012, p. 1). These rapid developments have facilitated the introduction of technology into our lives. As a matter of fact, the use of technology has affected every field and caused various changes. It can be stated that the field of education is one of the fields most affected by technological developments. Therefore, technology and the education process have been integrated, and a transformation has been experienced (Akkoyunlu & Kurbanoglu, 2003; Karakose et al. 2022). Technology constitutes one of the basic building blocks by bringing a new perspective to education. In light of these developments, it is possible to say that the concept of educational technology, which entered the literature, is an element that requires skilful use and evaluation of the available resources with certain methods and acts as a bridge to achieve the specific goals of education (Demirel, 2003).

2.1.1.2. The Importance of Technological Leadership for Teachers

Technology-induced changes in the physical structure of the school environment have brought about some changes in the learning-teaching process. As technological tools have become more frequently used in schools for educational purposes, new areas of responsibility have emerged for teachers. It is not easy for students to benefit from technological applications in education without the guidance of teachers. In order to get the highest level of efficiency from information technologies, activities such as teacher guidance and the ability to create a road map should be used effectively (Milli Eğitim Bakanlığı [MEB], 2007, p. 2). The stakeholders of educational organisations must cooperate at this point.

Supporting the use of technology in education with different methods has many contributions to teachers. It can be said that arousing the sense of curiosity in students and enabling them to look at the subject from different perspectives are the advantages of teachers' use of technology in education (Akkoyunlu & İmer, 1998; Lortoğlu, 2008). Tan (2005) emphasises that computer software with educational content motivates students to learn and increases their active learning levels by enabling them to enhance their visualisation skills. It is possible to say that they can learn the subjects that they have difficulty understanding more easily with multimedia-supported learning environments, they can repeat them as much as they want, and thus they realise more meaningful learning (Özmen, 2004). Considering all these, teachers have to be technology leaders.

2.2. Bibliometric Analysis

When the origin of the word bibliometrics is examined, it is seen that it emerged from the Greek words biblion, which means book, and metricus, which means unit of measurement, and means the science of measurement (Sengupta, 1992, as cited in Kurt, 2019, p. 16). When the historical development of the word bibliometrics is examined, it can be said that the concept of 'statistical bibliography', which was first included in Wyndham Hulme's book in 1922, formed the

basis of the word bibliometrics (Erdoğan, 2020, p. 8). Hulme explained the concept of statistical bibliography as a quantitative analysis of how scientific processes progress and defined it as 'the elucidation of the processes of science and technology through the counting of written documents' (Şimşir, 2021, p.8). The concept of bibliometrics was first used by Belgian library scientist Paul Otlet in 1934, but entered the literature in 1969 by Pritchard in the Journal of Documentation with the publication 'Statistical Bibliography or Bibliometrics?' (Elmas, 2021, p. 28).

Bibliometric analyses are used to observe changes by quantitatively analysing scientific studies, to reveal the relationship of a study with other studies, and to determine the general trends of the subject or field. These analyses are methods that enable quantitative visualisation of the definition, development and focal points of scientific publications. By eliminating personal interpretations, it enables the identification of the most effective publications and research areas. Although the emergence of bibliometric analysis is old, it has started to gain popularity again with the widespread use of online database platforms and the emergence of various analysis programmes. In bibliometric studies, data on scientific analyses are obtained by analysing certain characteristics of publications. In the analyses, the most effective researchers working on a subject and the dimensions of the interaction between them can be determined (Ulu & Akdağ, 2015). It is possible to say that technological developments have a significant impact on the increase in recent studies. Thanks to technological software, journals, authors, and institutions, keywords can be analysed and the results can be visualised (Zupic & Cater, 2015).

2.2.1. VOSviewer Analysis Programme

VOSviewer is a bibliometric analysis software introduced in 2010 by Nees Jan van Eck and Ludo Waltman from Leiden University. This software aims to reveal bibliometric networks based on a large amount of data obtained from various databases, such as PubMed, Scopus, and Web of Science (WoS), to create maps containing these links, to visualise, and finally to analyse the maps obtained (Erdoğan, 2020, p. 10). The word VOSviewer is a combination of the English words 'visualisation of similarity' and its Turkish equivalent, which means visualisation of similarity. For this reason, visuality is given importance in the graphic representations of the data obtained (Orhan, 2021, p. 113).

2.2.2. Web of Science Database

WoS, developed by Dr Eugene Garfield, is the most widely accepted, well-established, reliable, and widely used publisher-independent citation database in the academic community (Erdoğan, 2020, p. 9). WoS offers researchers the opportunity to search many academic publications. Researchers can access detailed analyses of different types of publications, such as articles, abstracts, proceedings, book chapters, publication reviews, and biographies, including the institution, year, country, journal, type of publication, language, and author of the publication. The WoS database scans more than 21200 refereed journals (Gürler, 2021, p. 55). According to the search result, it provides direct access to publications with an open access feature, and the institutions that financially support the publications are shown to the researchers (Erdoğan, 2020, p. 9).

3. Materials and Methods

In this study, the research area of teachers' technological leadership is analysed using science mapping and bibliometric analysis methods. These two methods of analysis provide a means to reveal the intellectual structure and current situation regarding teachers' technological leadership.

3.1. Data Search and Identification

For science mapping and bibliometric analysis, the platform from which the data will be obtained should be determined first. There are data platforms such as WoS, Scopus, and Google Scholar used worldwide. In this study, studies published in the WoS database were used. WoS database contains the publications of the most prestigious journals (SCI, SSCI, A&HCI, ESCI) that are internationally recognised. It offers a wide range of research opportunities to researchers. For this reason, data were taken from the WoS database.

At this point, firstly, the process of searching and defining the data, then refining and cleaning the data, and finally analysing the data was applied. As a result of this process, 400 articles were selected to be analysed. PRISMA (Preferred Reporting for Systematic Reviews and Meta-Reviews) diagram was used to report the data search and selection process.

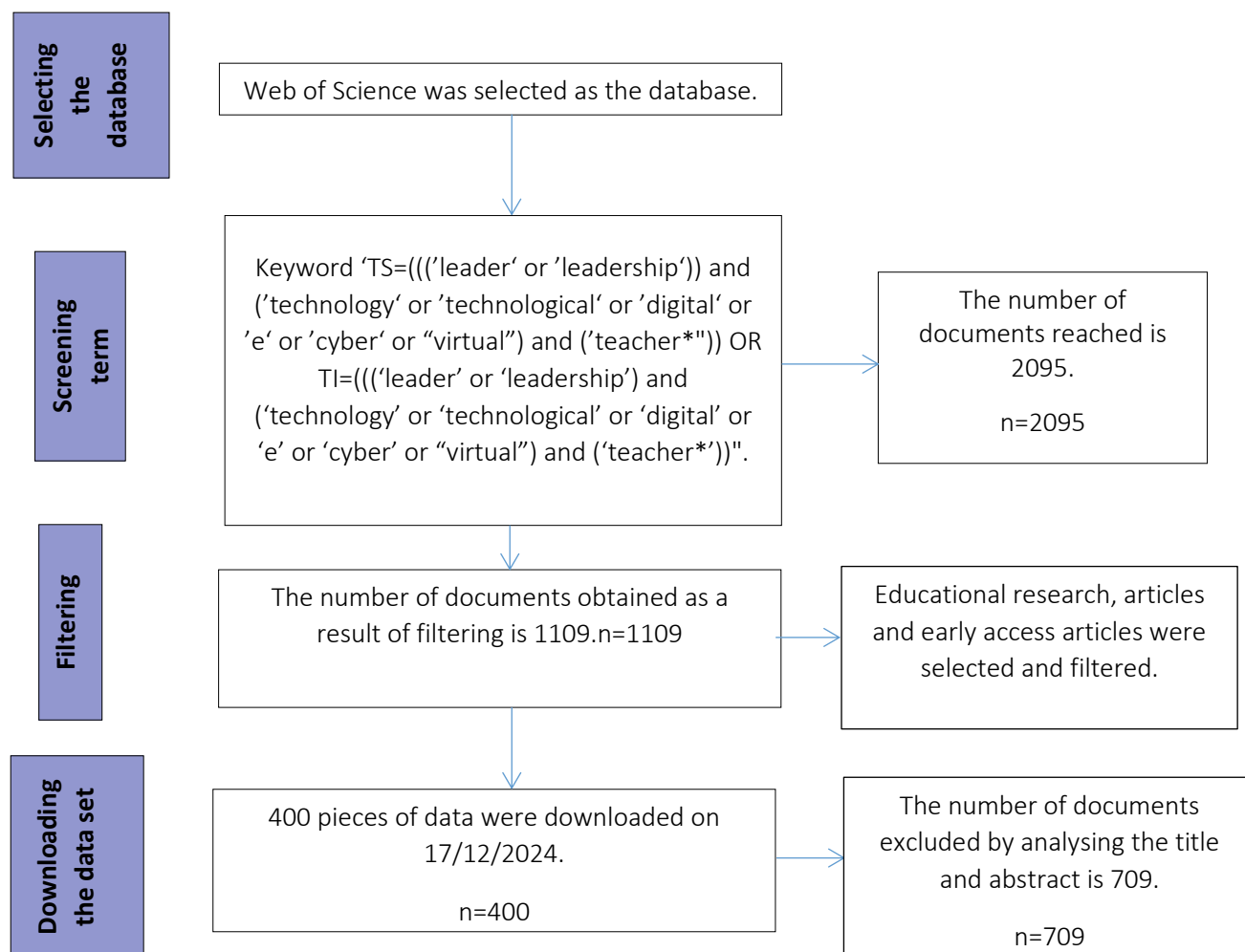


Figure 2. PRISMA flow diagram

Data for the analysis were selected according to the list of exclusion/inclusion criteria given in Table 1.

Table 1. Inclusion/Exclusion Criteria

Criteria	Inclusion	Exclusion	Rationale
Document Type	Journal articles	Books, book chapters, notices	Peer-reviewed, high-quality publications
Context	Only publications on Technological leadership of teachers	Publications on technological leadership of managers	Focusing on the teacher dimension of technological leadership
Database	Web of Science	Other databases (e.g. Scopus, Google Scholar, PubMed)	Publications of prestigious journals are available at

A keyword search was performed on the WoS database on 17 December 2024 using the following search term:

TOPIC=(((‘leader’ or ‘leadership’) and (‘technology’ or ‘technological’ or ‘digital’ or ‘e’ or ‘cyber’ or ‘virtual’) and (‘teacher*’)) OR TITLE=(((‘leader’ or ‘leadership’) and (‘technology’ or ‘technological’ or ‘digital’ or ‘e’ or ‘cyber’ or ‘virtual’) and (‘teacher*’)))

While selecting the keywords, a wide scan was conducted on teachers' technological leadership, and expert opinion was consulted to select words that would evoke these concepts. As a result, final keywords were created, and a search was made in the database. Firstly, 2095 data were obtained. As a result of the screening of these raw data, 986 studies were identified as not meeting one or more of the criteria given in Table 1 and were removed. The full texts of the studies in which the keywords within the scope of the search query of the study were not included in the abstract, and keywords on the obtained data were determined by examining the full texts of the studies by the researchers. Although keywords were not mentioned in the title while searching the abstract, these studies were included in the data set by the database due to the keywords mentioned in the abstract. Therefore, studies unrelated to the research topic were removed from the data set. During the study process, final data were obtained by taking expert opinion for the publications included and excluded by the researchers in the data set, and thus, the data set was recorded as 400 articles.

3.1. Data Extraction and Analysis

Gutiérrez-Salcedo et al. (2017) stated that there are two basic methods in bibliometric studies. It is stated that these methods are “performance analysis”, which enables the evaluation of the citation effect of scientific production of variables, and “science mapping” methods that aim to reveal the social, conceptual, and intellectual structure of scientific research. Considering the purpose of the research, one or both of these methods can be used (Öztürk, 2021). Depending on the purpose and research problems of this study, the studies published in the WoS database on teachers' technological leadership were analysed using both bibliometric methods, namely performance analysis and science mapping.

While analysing the data, firstly, descriptive analysis was performed. This analysis was carried out through the WoS system. Bibliometric analyses (performance analysis and science mapping)

were performed using VOSviewer software. In this context, citation, co-authorship, and common word analyses of the studies were performed. The analyses to be performed are explained in detail in Table 2.

Table 2. Table of Analyses to be performed

To determine the productivity of the research area	• The distribution of document types and publication years of the studies related to the research area were analysed.
To identify effective studies in the research area	• The most influential author, journal and country were determined by analysing the citations of the studies related to the research area.
To determine the social structure of the research area	• Co-author analysis of the studies related to the research area was carried out and the collaborations between the authors, the institutions of the authors and the countries where the institutions of the authors are located were examined.
To determine the conceptual structure of the research area	• The frequency and relationships of the words in the keywords of the studies related to the research area were analysed.

In the analysis in the VOSviewer programme, maps can be created for the network data. These maps can be visualised, and findings can be obtained as a result (Van Eck & Waltman, 2010). There are three types of visualisation in the VOSviewer software: Overlay Visualization, Network Visualization, and Density Visualization (Çevik, 2021). In addition, while analysing in the VOSviewer software, there are different weight parameters such as document, citation, and total link strength. Analyses can be made according to the number of documents of the author with the most studies, according to the number of citations received by the author with the most citations, or according to the link strength of a study with other studies. The weight of an item also shows the importance of that item. In this study, the results of the analysis are given by network visualisation, and ‘citation’ and ‘total link strength’ are selected as weight parameters.

4. Findings

4.1. Descriptive Analyses

The WoS database was searched with the search term ‘TS=(((‘leader’ or ‘leadership’) and (‘technology’ or ‘technological’ or ‘digital’ or ‘e’ or ‘cyber’ or ‘virtual’) and (‘teacher*’)) OR TI=(((‘leader’ or ‘leadership’) and (‘technology’ or ‘technological’ or ‘digital’ or ‘e’ or ‘cyber’ or “virtual”) and (‘teacher*’))’ and 2095 data were obtained. Some filtering criteria were applied to the obtained data. Articles and early access articles were selected as the document type, and 1106 data were obtained by selecting educational research as the research category. Even if there are no keywords in the ‘Title’ section of these studies, if there are keywords scanned in the ‘Topic’ section, the studies were included in the list. For this reason, 400 studies were downloaded on 17/12/2024 by removing the studies that were not related to the research topic, and a data set was created.

In descriptive analyses, the distribution of studies according to document types and years was examined. The analyses were carried out through the WoS database's own system.

Table 3 shows the document types of the studies on teachers' technological leadership conducted between 1999 and 2024.

Table 3. Document Types

Document Types	Number of Documents	Document Percentage
Article	387	96,75
Early Access Article	13	3,25

It was determined that 387 of the 400 studies analysed in total were articles and 13 were early access articles on 17 December 2024, when the data were obtained.

4.1.1. Distribution of Articles by Year

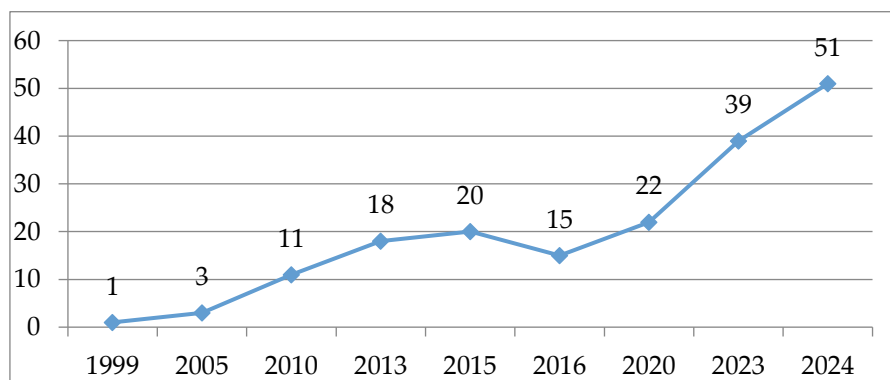


Figure 3. Distribution by Years

When the studies published in the WoS database on teachers' technological leadership were examined; it was observed that the first article was published in 1999, there was a very small increase in the number of studies from 1999 to 2005, the number of studies continued to increase since 2005, and although there was a decrease in 2016, there were more than twenty studies per year since 2020. The increasing importance of technology due to the COVID-19 pandemic has led to this result.

4.2. Bibliographic Findings

The citation (author, journal, country), co-authorship (author, institution, country), and co-word network structures of the articles were examined by conducting science mapping and performance analyses of 400 articles published in the WoS database until 17/12/2024. The findings obtained in these analyses were obtained through VOSviewer software. The results revealed the global impact of publications in the research area.

4.2.1. Citation Analysis

Citation analysis is a type of analysis in which the relationship between publications, authors, countries of origin, and organisations of publication is revealed. In the citation analysis of the studies on teachers' technological leadership, the most effective documents, sources, authors, journals, and countries were determined.

4.2.1.1. Most Influential Authors

In the citation analysis performed to determine the most influential authors in the VOSviewer programme, the minimum number of publications of an author was determined as two, and the minimum number of citations of an author was determined as 1. Accordingly, 85 authors out of 1003 authors reached the threshold value. When the most influential author analysis is examined, it is seen that there are 7 clusters expressed in different colours, a total of 59 authors within these clusters, and 243 links between clusters. When ‘citation’ was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 4 was obtained.

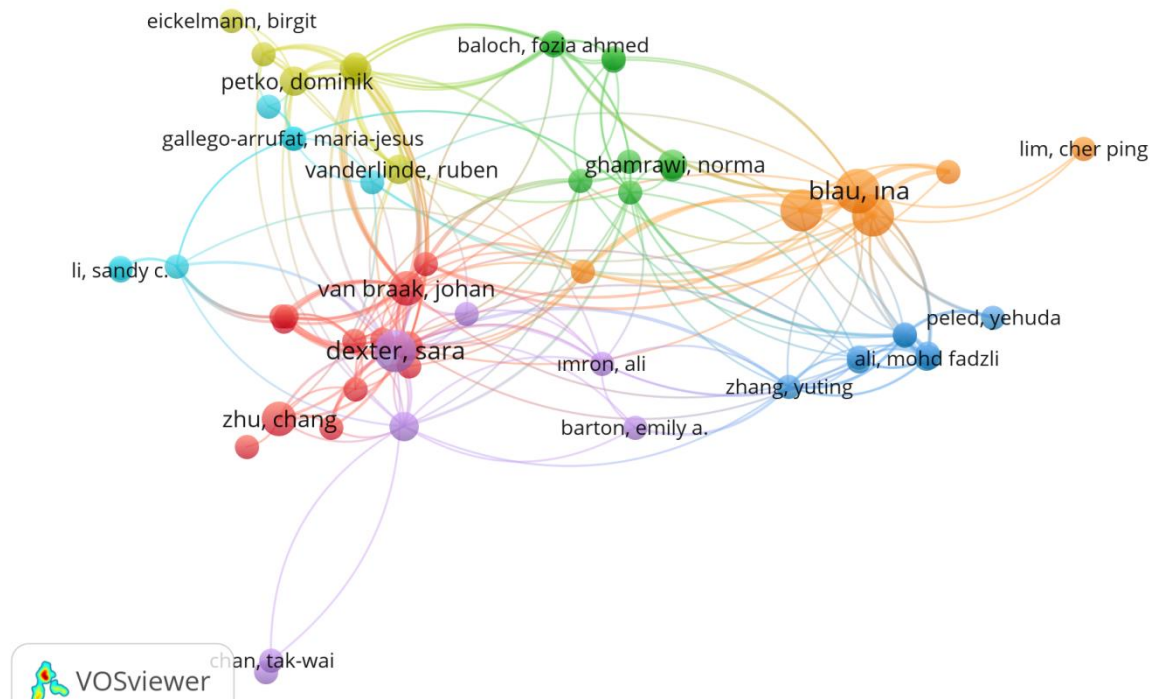


Figure 4. Network Structure of Most Cited Authors

When the circle sizes in the network structure obtained as a result of the analysis to determine the most cited authors are analysed, the largest circles belong to the authors named Ina Blau, Johan Van Braak, Sara Dexter, and Chang Zhu.

When ‘total link strength’ is selected as the weight parameter in the VOSviewer programme, the network structure obtained does not change since the network structure is created over the same table. However, the ranking of the authors with the most citations and the ranking of the authors with the highest link strength change. Therefore, the ranking according to “citation” and “link strength” are given in different tables below.

Table 4. Number of Articles, Citations and Link Strength of the Most Cited Authors

Author	Number of Articles	Number of Citations	Total Connection Power
Johan Van Braak	4	559	37
Jo Tondeur	3	503	32
Joke Voogt	2	426	7
Fanny Pettersson	2	265	22
Ina Blau	7	209	53
Tamar Shamir-Inbal	6	173	49
Sara Dexter	6	160	36

When Table 4 is analysed, the author with the highest number of citations is 'Johan Van Braak' with 559 citations. In the second place is Jo Tondeur with 503 citations, in the third place is Joke Voogt with 426 citations, and in the fourth place is Fanny Pettersson with 265 citations. Despite the high number of citations, some authors do not appear in the network structure. This is because the connection power of that author is weak because that author has done less work with other authors.

Table 5. Authors with the Highest Total Connection Strength and Connection Strengths

Author	Total Conneciton Power
Ina Blau	53
Tamar-Shamir-Inbal	49
Johan Van Braak	37
Sara Dexter	36
Jo Tondeur	32
Fanny Pettersson	22
I-hua Chang	22

When the table created according to the total link strength is analysed, the first three authors with the highest number of links are Ina Blau with 53 links, Tamar Shamir-Inbal with 49 citations and Johan Van Braak with 37 citations. It is possible to explain the reason why these authors are in the first place is that they collaborate more with other authors.

4.2.1.2. Most Effective Sources/Magazines

In the citation analysis performed to determine the most influential journals in the VOSviewer programme, the minimum number of articles of a journal was determined as 2, and the minimum number of citations of a journal was determined as 1. Accordingly, 65 of 176 journals reached the threshold value. When the most influential journal analysis is examined, it is seen that there are 9 clusters expressed in different colours, a total of 49 journals within these clusters, and 184 links between clusters. When "citation" was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 5 was obtained.

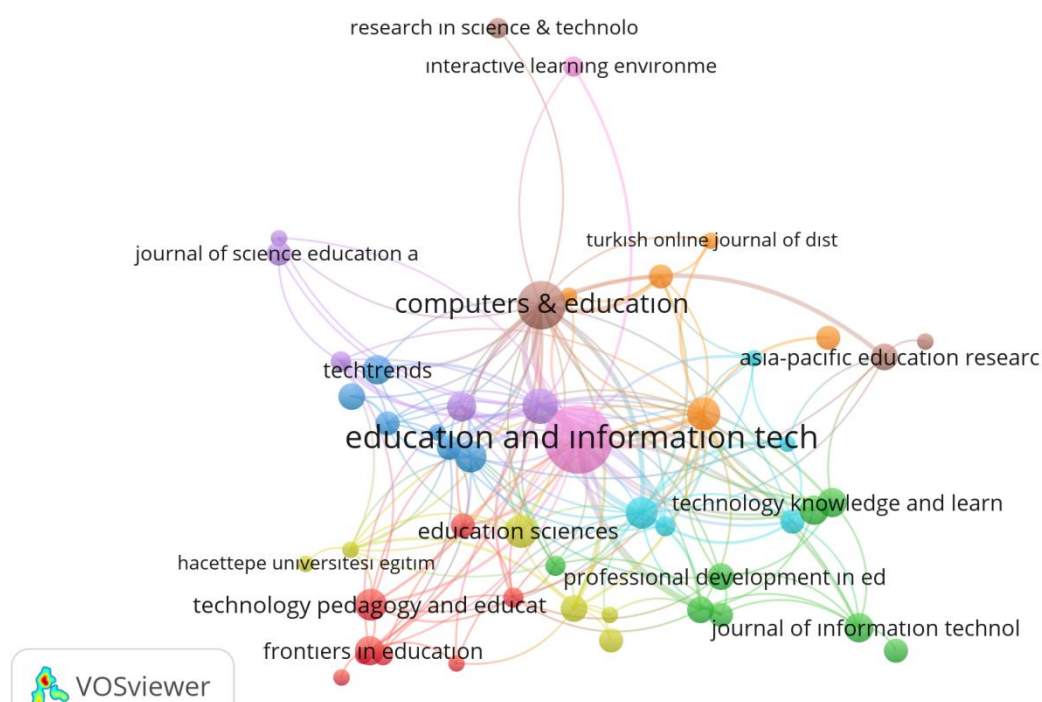


Figure 5. Network Structure of the Most Cited Journals

When the network structure obtained according to the most cited journals is analysed, it is seen that the concentration is distributed to more than one cluster, and the lines in the network structure are dense and complex. It is possible to say that this situation is due to the similarity of citations between the studies published in the journals.

When 'total link strength' is selected as the weight parameter in the VOSviewer programme, the network structure obtained does not change since the network structure is created over the same table. However, the rankings of sources by citations and by link strength change. Therefore, the ranking according to "citation" and "total connection power" are given in different tables below.

Table 6. Number of Articles, Citations, and Total Link Strength of the Most Influential Journals

Resources	Number of Articles	Number of Citations	Total Connection Power
Computer & Education	16	1109	63
Education and Information Technologies	33	566	83
Journal of Research on Technology in Education	9	223	50
Education Technology & Society	8	166	39
Journal of Computer Assisted Learning	4	164	9
Etr&d Educational Technology Research and Development	7	153	15
Technology, Pedagogy and Education	7	150	10

When the journals with the highest number of citations are analysed, 'Computer & Education' ranks first with 1109 citations. 'Education and Information Technologies' ranks second with 566 citations and 'Journal of Research on Technology in Education' ranks third with 223 citations. When the number of articles and the total number of link power of the journals are also analysed, they are in the first three places. In this case, it is possible to say that the most effective publications in the field of technological leadership are published in these journals.

Table 7. Total Link Strength of the Most Influential Journals

Magazines	Total Connection Power
Education and Information Technologies	83
Computer & Education	63
Journal of Research on Technology in Education	50
Education Technology & Society	39
British Journal of Educational Technology	33
International Journal of Instruction	18
Journal of Educational Administration	16

It is seen that the total number of link strengths of the journals in the first four places in the ranking of the journals with the highest number of citations is also high. It is known that the 'British Journal of Educational Technology' in the fifth place is in the field of educational technology, the 'International Journal of Instruction' in the sixth place is in the field of educational sciences, and the 'Journal of Educational Administration' in the seventh place is in the field of educational administration.

4.2.1.3. Most Influential Countries

In the citation analysis performed to determine the most effective countries in the VOSviewer programme, the minimum number of documents of a country was determined as 2, and the minimum number of citations of an organisation was determined as 1; accordingly, 43 out of 71 countries reached the threshold value. When 'citation' was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 6 was obtained.

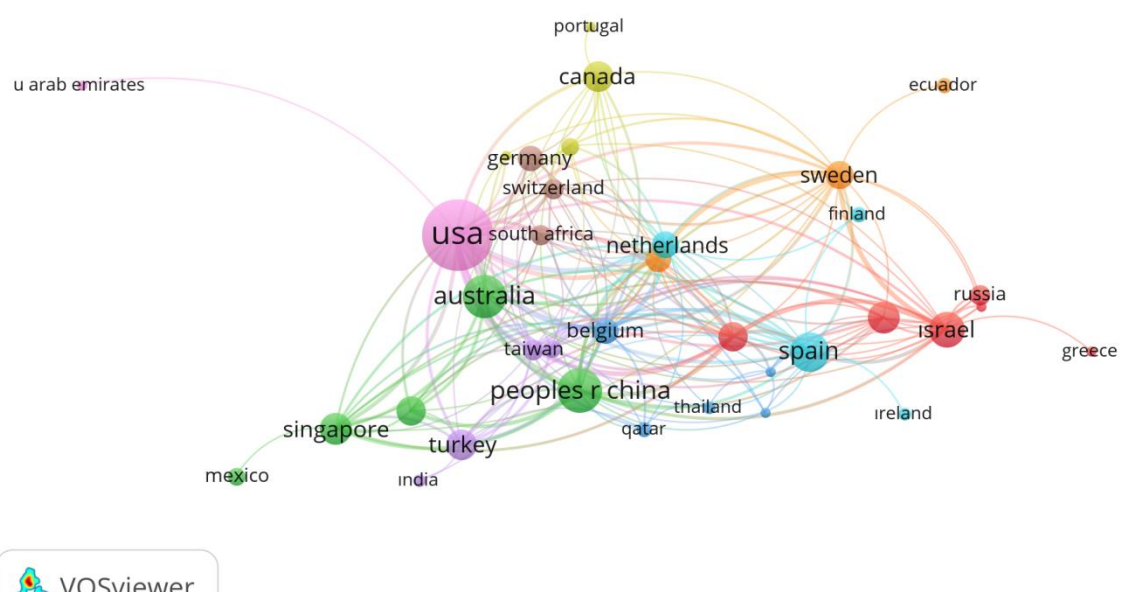


Figure 6. Network Structure of the Most Cited Countries

When the network structure obtained from the analysis of the most cited countries is examined, it is found that there are 9 clusters expressed in different colours, a total of 36 countries within these clusters, and 189 connections between clusters. The network structure between countries is relatively simple, and countries such as Greece, the United Arab Emirates, Mexico, and Ecuador are outside the network structure. According to the network structure, these countries are less cooperative with the countries in the centre.

When 'total link strength' is selected as the weight parameter in the VOSviewer programme, the network structure obtained does not change since the network structure is created over the same table. However, the rankings of countries by both the highest number of citations and the highest link strength change. Therefore, the ranking according to 'citation' and 'connection strength' is given in different tables below.

Table 8. Number of Articles, Citations, and Total Link Strength of the Most Cited Countries

Countries	Number of Articles	Number of Citations	Total Connection Power
USA	84	1610	135
China	34	728	71
Belgium	11	712	74
Netherlands	12	685	52
Sweden	14	349	51
Israel	21	325	49
Spain	27	274	47

When the table of the countries with the highest number of citations is analysed, the country with the highest number of citations and total linking power, located in the centre, is the USA. China ranks second with 728 citations, and Belgium ranks third with 712 citations. It can be said that the presence of the most cited universities in these countries is effective in the formation of this ranking.

Table 9. Countries with the Highest Total Connection Power and Connection Power

Countries	Total Connection Power
USA	135
Belgium	74
China	71
Malaysia	60
Taiwan	56
Netherlands	52
Sweden	51

It is noteworthy that the top three countries in the total link strength ranking are also the countries with the highest number of citations. It can be considered that the Asian countries ranked fourth and fifth are ranked as a reflection of the importance they attach to technology in education.

4.2.2. Co-author Analysis

Co-author analysis was conducted to determine the social structure of the studies on teachers' technological leadership. In the co-author analysis, collaborations between authors, authors' institutions, and countries where authors' institutions are located were examined.

4.2.2.1. Analysing Collaborations between Authors

In the co-author analysis performed to determine the relationship between authors in the VOSviewer programme, the minimum number of documents for an author among 400 articles was determined as two, and the minimum number of citations as 1. Accordingly, 85 authors out of 1003 authors fulfilled the threshold value. However, among these authors, 13 authors who have a connection with each other were identified. The network structure was created accordingly. When 'citation' was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 7 was obtained.

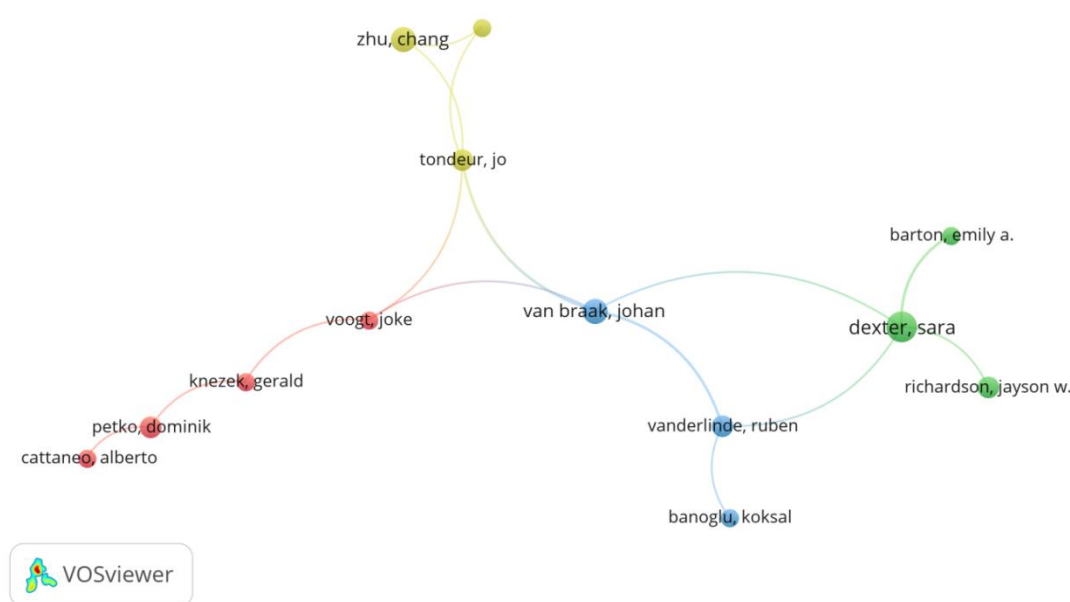


Figure 7. Network Structure of Relationships between Authors

When the analysis of the collaborations between authors is examined, it is seen that there are 4 clusters expressed in different colours, a total of 13 authors within these clusters, and 15 links between clusters. It is seen that the authors do not have strong relationships with each other. It is possible to say that the reason for this is that they do not participate in joint studies. When we look at the circle sizes formed, it is seen that the highest concentration is on Johan Van Braak, Sara Dexter, and Joke Voogt. Another author who draws attention to the network structure is Köksal Banoğlu.

4.2.2.2. Analysis of Collaborations between Authors' Institutions

In the co-author analysis performed to determine the relationship between institutions in the VOSviewer programme, the minimum number of documents for an institution from 400 articles was determined as two and the minimum number of citations as 1. Accordingly, 105 institutions out of 500 institutions met the threshold value. However, 105 institutions in the data set were not found to be related to each other. Twenty institutions with a relationship between them were identified, and the network structure was created accordingly. When 'citation' was selected as the

weight parameter in the VOSviewer programme, the network structure given in Figure 10 was obtained.



Figure 8. Network Structure of Relationships between Authors' Organisations

When the analysis of the collaborations between the authors' institutions is examined, it is seen that there are 5 clusters expressed in different colours, a total of 20 institutions within these clusters and 27 connections between clusters. When the network structure is analysed, it is seen that the relationship network between institutions is weak. It is possible to say that the reason for this is that the authors within the university do not take part in co-authored studies.

4.2.2.3. Analysing the Collaborations between the Countries where the Authors' Institutions are Located

In order to determine the relationship between countries in the VOSviewer programme, the minimum number of documents for a country from 400 articles was determined as 2 and the minimum number of citations as 1. Accordingly, 43 countries out of 71 countries met the threshold value. However, among these countries, 36 countries with a connection with each other were identified and the network structure was created accordingly. When 'citation' was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 9 was obtained.

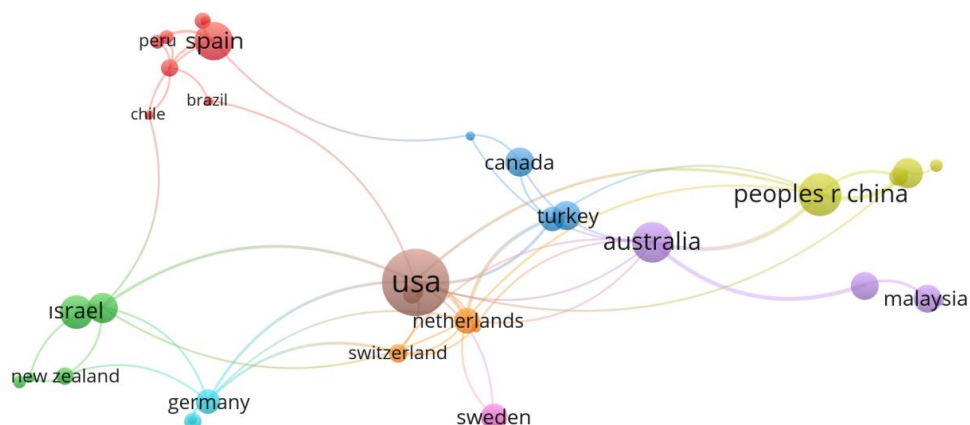


Figure 9. Network Structure of the Relationships between the Countries where the Authors' Institutions are Located

In the network structure, there are 9 clusters expressed in different colours, a total of 36 countries within these clusters and 61 connections between clusters. When the network structure

is analysed, it is seen that the country at the centre with the highest number of connections is the USA. The USA is in cooperation both in its own cluster and with the countries in other clusters. It is possible to say that China, in the yellow cluster, Spain, in the red cluster, and Australia, in the purple cluster, are the countries with the highest number of references within their clusters. Turkey, which is in the blue cluster, has the highest number of citations within its cluster and is also in cooperation with other countries. In this case, it is possible to talk about the effectiveness of the studies carried out in the field of technological leadership in our country.

4.2.3. Common Word Analysis

In order to determine the conceptual structure of the studies on teachers' technological leadership, common word analysis was performed. The frequency of use of the words in the articles and the relationship network between them were analysed.

4.2.3.1. Analysing the Most Used Keywords

In order to determine the most used keywords in the VOSviewer programme, the minimum number of uses of a keyword from 400 articles was determined as 5. Accordingly, 50 keywords out of 1159 keywords met the threshold value. When 'frequency of use' was selected as the weight parameter in the VOSviewer programme, the network structure given in Figure 10 was obtained.

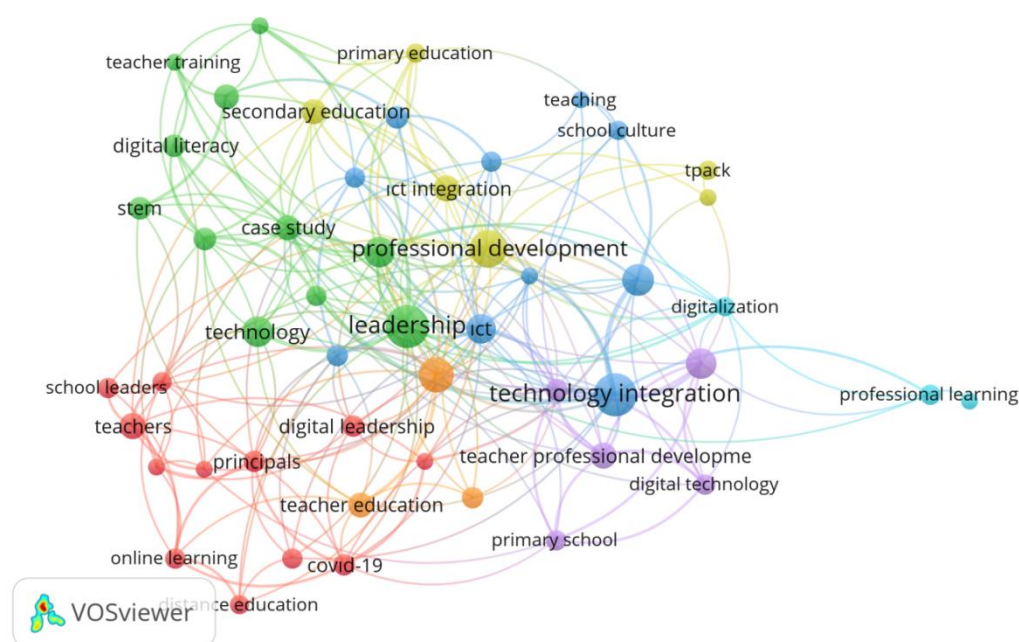


Figure 10. Network Structure of Most Used Keywords

When the common-word analysis was examined, it was determined that there were 7 clusters shown in different colours, a total of 50 keywords within these clusters and 233 connections between clusters.

In the network structure, the size of the circles representing concepts expresses their frequency of use. For this reason, "leadership" has the largest circle size with 31 uses as a keyword in the centre. As the links between keywords become thicker, the strength of the connection between them increases, and as the links become thinner, the strength of the relationship decreases. Accordingly, it is seen that the link between the concepts of "teachers" and "online learning" in the red cluster is thicker because they are used more than other concepts. It is possible to say that the connection between the words "primary school" and "digital technology" in the purple coloured cluster has a low relationship strength as it appears to be quite thin.

When the network structure is examined, there are 12 keywords in the cluster expressed in red colour. The words with the highest concentration in this cluster are “digital leadership”, “teachers”, “online learning”, “school leaders”.

There are 11 keywords in the cluster expressed in green. The words with the highest concentration in this cluster are “leadership”, “teacher leadership”, “teacher”, “digital literacy”.

There are 10 keywords in the cluster expressed in blue colour. The words with the highest concentration in this cluster are “technnology integration”, “technology leadership”, “educational leadership”.

The most used keywords, their frequency of use and link strengths are shown in table 10.

Table 10. Most Used Keywords, Frequency of Usage and Connection Strengths

Keywords	Frequency of Use	Total Connection Power
Leadership	31	31
Technnology integration	30	33
Professional development	23	29
Education al technology	20	2
Technology leadership	17	16
School leadership	15	20
Technology	15	14

When Table 10 is analysed, it is seen that the word with the highest frequency of use is “leadership” with 31 uses. The second word is “technology integration” with 30 uses, the third word is “professional development” with 23 uses, the fourth word is “educational technology” with 20 uses, and the fifth word is “technology leadership” with 17 uses. The link strengths of the words with high frequency of use are also high. This shows the effectiveness of the studies that use keywords.

5. Discussion

In this study, the twenty-five-year adventure of the research on teachers' technological leadership in the international index in the WoS database is presented with a holistic evaluation approach. In this context, 400 articles related to the research topic in the WoS database were analysed according to nine sub-problems. This study is the first study to reveal the trends and current situation regarding teachers' technological leadership in the last twenty-five years, from 1999 to 2024.

According to the results of the descriptive analysis, 96.25 percent of the studies were articles and 3.75 percent were early access articles. Looking at the studies by year, a decrease in the number of articles is observed between 2015 and 2016, while an increase is observed in all other years compared to the previous year. Especially, the rate of articles published after 2020 has increased.

The most influential authors, journals and countries in the field were analysed. In the analysis of the most influential authors, it is seen that Johan Van Braak, Jo Tondeur, and Joke Voogt are in the top three in the citation ranking. There are similar studies in the literature. In the thesis study of Çetinkiran (2022) on ‘Bibliometric Analysis of Turkey-based International Publications on Technological Pedagogical Content Knowledge’, Jo Tondeur ranks second in the order of the most

cited authors. Although the number of Joke Voogt's articles is low, the high number of citations shows that he has made a significant contribution to the field. Joke Voogt is also the author with the lowest link strength. This means that the author collaborates less with other authors. Ina Blau, who ranked fifth, was the author with the highest number of documents and total link strength. For this reason, it can be said that the author has collaborated more. Looking at the ranking according to link strength, Ina Blau Tamar, Shamir-Inbal and Johan Van Braak are in the first place. These authors are also the authors with the highest number of articles, which is a key factor in their high link strength.

When the citation ranking of the most influential journals is analysed, it is seen that 'Computer & Education', 'Education and Information Technologies' and 'Journal of Research on Technology in Education' are the top three journals. These journals are also the three journals with the highest linking power. In this sense, they are the most effective journals in the field. In the thesis study of Çetinkiran (2022) on 'Bibliometric Analysis of International Publications Sourced from Turkey on Technological Pedagogical Content Knowledge', it was emphasised that the journal with the highest impact value was the journal named 'Computer & Education'.

When the citation analysis of the most influential countries is analysed, it is seen that the USA, China, and Belgium take the first places. These countries are also the countries with the highest connection power. The presence of the most cited universities in these countries has an effect on the ranking. In the thesis on 'Bibliometric Analysis of Distance Education Themed Articles Published in the Web of Science Database' by Ertekin (2022), it was concluded that the countries with the highest number of publications and citations are the USA and China.

In the co-author analysis conducted to determine the social structure, the relationships between authors, authors' institutions, and the countries where authors' institutions are located were analysed. In the co-author analysis, the relationships between authors were found to be weak. It is possible to say that Johan Van Braak, Sara Dexter, and Joke Voogt are the authors with the most co-authorship studies. Another name that draws attention in the network structure is Köksal Banoğlu. Köksal Banoğlu took part in the network structure with his co-authorship work with Vanderlinde & Çetin (2021). When the relationship between the institutions of the authors is examined, it is seen that the inter-institutional network is weak. The university with the largest circle size and the highest number of co-authored studies was 'Nanyang Technological University'. When the relationship between the countries where the authors' institutions are located is examined, it is seen that the USA is at the centre. The USA is the country with the highest number of citations and total linking power. There are similar studies in the literature. In the study of Duman (2024) on 'Biblio-metric Analysis of Educational Research on Coding Listed in Web of Science with VOSviewer', it is stated that the country with the highest number of co-authorship studies is the USA. Other countries with the highest number of citations and link strength were China, Belgium, the Netherlands, and Sweden. Turkey ranked thirteenth with 153 citations. In this context, it is possible to say that the contribution of co-writing studies conducted in Turkey to the field is high.

In the common-word analysis conducted to determine the conceptual structure, the most frequently used concepts were analysed. The frequency of use and the relationship network of the keywords used in the studies were revealed. The first five most frequently used keywords were leadership with 31 frequency of use, technology integration with 30 frequency of use, professional development with 23 frequency of use, educational technology with 20 frequency of use, and techno-logical leadership with 17 frequency of use. It was observed that the words with high frequency of use also had high connection strengths. The words teachers and teacher leadership were ranked twelfth and fourteenth in the list. In the thesis study of Çetinkiran (2022) on 'Bibliometric Analysis of Turkey-based International Publications on Technological Pedagogical

Content Knowledge', it was concluded that technology integration was one of the most frequently used keywords.

6. Conclusions

As a result, the study analysed publications, authors, countries, journals, source types, citation counts, and collaborations that are leading in the field of teacher technological leadership. A framework has been established for many components, such as current research topics and future research trends. At this point, it is believed that this study will reflect trends and current issues related to teachers' technological leadership and will play an active role in conducting different studies in this field.

7. Recommendations

1. According to research findings, the lack of international studies conducted in Turkey on technological leadership is striking. Therefore, it is recommended that studies conducted within universities and related institutions be encouraged and that this topic be made a priority area of study. Conducting similar studies on other samples that predict other personality factors, such as agreeableness.

2. Studies on STEM applications in education, artificial intelligence-supported education, digital learning, and policies and strategies for educational technologies in Turkey have been noteworthy in recent years. In this regard, in-service training can be organised to enable teachers to use these technologies effectively and take a leadership role. Such training should be prioritised so that teachers can become leaders of technological transformation. More studies should be conducted to examine how family environment and personality traits influence students' academic performance, classroom behavior, peer relationships, and teacher-student interactions.

3. Local research on how artificial intelligence applications and new-generation digital tools can be integrated into classrooms can be supported. This will enable teachers to develop new approaches that combine education and technology leadership.

4. An in-depth analysis of the most frequently used key concepts can be performed. The framework and contexts of the same keywords used in different studies can provide a roadmap for conceptual clarity in the field.

5. Only WoS data was used in this study. Including different international databases, such as Scopus, in future studies may provide more comprehensive and comparative results for the field.

6. It is believed that the analyses conducted with VOSviewer in this study successfully reveal the general trends in the field. However, it may be recommended to use different application software, such as Bibliometrix (R) and SciMAT, together. This is believed to enable a multidimensional and more comprehensive analysis of the studies.

Declarations

Author Contributions. H.B: Conceptualization, design, data acquisition, data analysis, drafting manuscript. R.Y: Conceptualizing, data analysis, critical revision of the manuscript, writing, editing/reviewing.

Conflicts of Interest. The authors declare no conflict of interest.

Data Availability Statement. The data supporting the findings of this study are available from the corresponding author upon request. All datasets were collected and stored in compliance with institutional research ethics and privacy guidelines.

Acknowledgements. This paper is based on the first author's Master's thesis, which was completed at the Social Sciences Institute of Kahramanmaras Sutcu Imam University as part of the Educational

Administration programme, under the supervision of the second author. The authors would like to thank the reviewers for their valuable and constructive feedback.

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About the Contributor(s)

Hilal Barak, Information Technologies Teacher, Kahramanmaraş.

Email: hilalbrk.4@gmail.com

ORCID: <https://orcid.org/0009-0007-3411-7871>

Ramazan Yirci, Prof. Dr., Kahramanmaraş Sütçü İmam University - Department of Educational Sciences, Educational Administration Program

Email: yirci@ksu.edu.tr

ORCID: <https://orcid.org/0000-0003-4696-7420>

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