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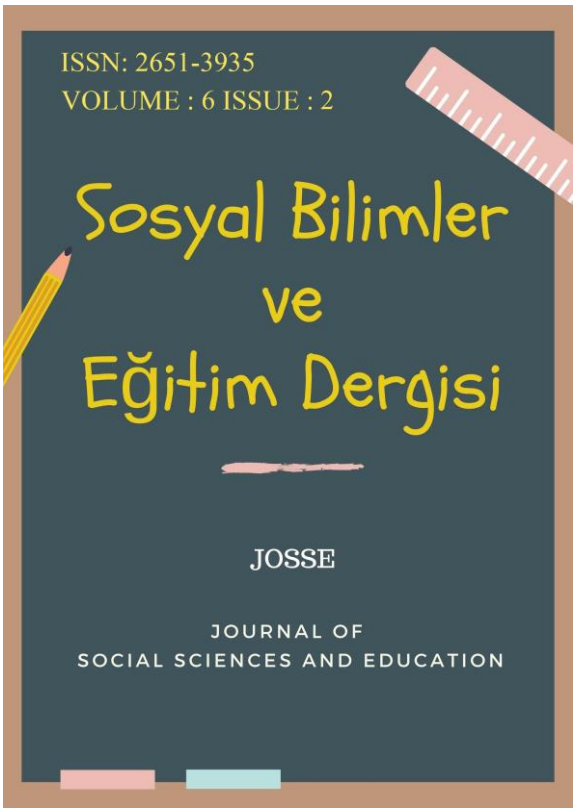

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Content Analysis of Articles on the Technological Pedagogical Content Knowledge of Secondary School Science Teachers in Türkiye

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Abstract

In this study, it is aimed to examine the trends of the studies on technological pedagogical content competencies and technology integration of science teachers in Türkiye in the last 10 years in terms of purpose, year of publication, journal of publication, method, sample selection, data collection tools, data analysis and remarkable results of the studies. In this direction, content analysis method was used in the research. A total of twenty-one academic articles accessed from Web of Science, EBSCOHOST and Google Scholar databases including Türkiye index were analyzed in August 2023. The data were analyzed by content analysis. The analyzed data were presented in the form of tables and graphs with the help of percentages and frequencies. As a result of the research, it was determined that the most common purpose of the studies was "determining TPACK levels and examining them in terms of various variables", the most publications were in 2016 and 2019, the related studies were mostly published in "Education and Science", "Education and Information Technologies" and "Gazi University Journal of Gazi Educational Faculty" journals, the most frequently used method was quantitative, the most frequently used sample group was convenient sampling / easily accessible sampling, the most frequently used data collection tool was scale and the most frequently used data analysis was Anavo-Ancova. Among the remarkable results of the studies, it was determined that "Teachers' TPACK levels are high". It is recommended that more in-depth and detailed qualitative research be conducted on TPACK for science teachers.

Keywords: Technological pedagogy, technology integration, technological pedagogical content knowledge, science teachers, content analysis

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Introduction

Technology is generally the application of knowledge and science for a specific purpose. Technology also has different meanings in different disciplines. In today's modern technology age, the place of technology in human life is undeniable. Because technology makes people's lives easier. Every situation undertaken by humanity is dependent on the development of science and technology. In this sense, technology has a facilitating effect in meeting the current life needs of humanity. Technology is used in multiple disciplines such as engineering, design, industry, and education. Perhaps the most important use of technology in terms of directly touching human life is its use in education. Therefore, based on the progress in science and technology, technology has entered the modern understanding of education and lifestyle (Banta, 2009; Gershon, 2017; Sudarsana et all., 2019). Today, such an integration of technology into lifestyles has triggered its use in teacher education. Simulations, virtual laboratories, mobile devices, technological games, creative and artistic activities are some of the areas where technology is used in teacher education (Adedokun et al. 2012; Anderson & Barnett 2013; Leonard et al. 2016; Pierson & Clark, 2018; Scalise & Clarke-Midura 2018; Voyles, Fossum & Haller 2008; Weintrop et al. 2016; Scalise et al. 2011).

Education is recognized as one of the most fundamental elements in the development and progress of societies. With the rapid advancement of technology, there are transformations in the field of education (Akyıldız & Altun, 2018). In this digital age where students can easily access information, technology-supported education methods have gained significant importance in addition to traditional teaching approaches. Technology can be used to enrich students' learning experiences, improve the quality of education, and enable teachers to guide students more effectively. At this point, educational technology and technological pedagogy content knowledge come to the fore (Dündar & Ünaldı, 2023). Technological pedagogy is an interdisciplinary concept that aims to increase the effectiveness of teaching and learning processes by combining the use of technology and pedagogical processes in the field of education. This approach integrates technological tools and methods into education to transform traditional education models in accordance with the needs of the age (Açıkgül & Aslaner, 2015; Güler & Bilici, 2016). In technological pedagogy, a student-centered teaching approach is adopted in which technology is included in the education service, as opposed to traditional teaching methods in which information is transferred and the student is passive (Taskin Ekici & Dereli, 2022).

As a result of the intertwining of technology and education, "Technological Pedagogical Content Knowledge (TPACK)" becomes more important for teachers' professional development. TPACK covers the whole set of knowledge and skills necessary for teachers to use technology by integrating it into education in line with educational goals and to create effective learning. (Karakuyu & Karakuyu, 2016). Therefore, teachers' technological pedagogical content competencies play a critical role in supporting and guiding students in the most effective way in accordance with the teaching and learning needs of the age (Doğru & Aydın, 2018). In today's conditions, it is thought that teachers will participate more actively in educational processes thanks to technology pedagogy. Thanks to teachers' technological pedagogical content knowledge, technology-supported educational materials such as interactive content, virtual experiences and digital tools can be implemented in classrooms. As a result, teachers can make the course content more effective and attractive by using technology more effectively, increase students' interest in the course by providing them with a unique and creative learning experience, and provide students with personalized learning opportunities. This enables students to understand the lesson more effectively and learn the information in a more permanent way (Akgündüz & Bağdiken, 2018; Ünal Çoban et al., 2022). Teachers' technological pedagogical content knowledge can have a direct impact on students' academic achievement and learning motivation. While the use of technology-supported education methods attracts students' attention, it can also improve their skills such as “critical thinking”, “problem solving” and “creativity” (Balçın & Ergün, 2018; Bıçak & Şeker, 2022). Technology can contribute to equality of opportunity in education by democratizing access to information. Especially in rural areas or disadvantaged students can be offered educational opportunities in big cities with technology-supported education (Kırındı & Durmuş, 2019). Of course, teachers have a key role here and contribute to equality of opportunity when they have the ability to use technology effectively and adapt educational materials appropriately to students (Akyıldız & Altun, 2018).

Today, science education is one of the fields responsible for raising science literate individuals and developing critical thinking skills and 21st century skills. Science education is therefore considered to be the most integral part of education today. In recent years, advances in information and technology have had a complex but positive impact on science teaching and learning (Kalogiannakis, Papadakis & Zourmpakis, 2021). In this sense, science educators agree that the use of technology in education has a strong and positive impact on teaching and learning. They also advocate the promotion of technology in education to

improve students' understanding of science, actively engage them in the learning process, and prepare them for the needs of the current workforce in accordance with the requirements of the 21st century. With the increasing accessibility of technology, science teachers have started to use technology more in science teaching to demonstrate science concepts and reveal the relationship between concepts, to promote students' learning, and to develop their problem solving skills (Lee et al., 2011; Pringle, Dawson & Ritzhaupt, 2015). In line with the objectives of the science curriculum, science teachers will be able to provide students with active and permanent learning through the integration of technology (Timur & Erzengin, 2019). For these to be realized, science teachers should have competence in TPACK.

The roles of secondary school science teachers have transformed significantly with changes in technology and pedagogical fields. While traditional teacher roles emphasized knowledge transfer and disciplinary instruction in the classroom, technological developments and changing trends in education have required teachers to assume more effective and multifaceted roles (Meriç, 2014). At the same time, the widespread use of technology has changed students' interests and learning processes. Students now have instant access to information and can conduct research using online tools. At the same time, students can be overwhelmed by information pollution and sometimes have difficulties in understanding what is right and what is wrong. Therefore, the role of teachers has evolved to be not only a provider of information, but also a guide in the process of developing the ability to critically evaluate information and to distinguish correct information (Yalçın & Kutluca, 2023). With this change, the professional roles of teachers have also expanded. Technological pedagogy requires teachers to continuously focus on their own professional development and increase their TPACK. For the teachers to develop skills such as using technology tools effectively, evaluating digital content and guiding students on online platforms is important for teaching processes. Moreover, teachers with technological pedagogical knowledge are responsible for increasing students' digital literacy levels and guiding them to navigate the digital world safely (Tatlı et al., 2016). This change and development in the roles of secondary school science teachers has become more important with the using inreasingly technology in education and the adoption of student-centered teaching approaches (Cesur Özkara et al., 2018).

It is not surprising that the field of science education worldwide has seen a significant increase in recent years in research aimed at analytically examining the pedagogical use of modern technologies. Although such a trend has led to the emergence of the Journal of

Science Education and Technology specifically, such research is scattered across a wide range of educational journals. Our main objectives were to summarize the current state of research on teachers who are familiar with modern technologies and can blend them with science education (i.e., have technological pedagogical content knowledge) and to identify themes and gaps in this research base.

It is natural that there are studies in recent years aiming to examine the use of new technologies in science education, which are increasing in the world. Although the emergence of such studies is in the "Journal of Science Education and Technology", such studies are also included in different journals. In this study, TPACK was examined in the field of science education by reviewing the literature in a limited and purposeful way. The main goal here is to examine the studies on TPACK with science teachers. To summarize, the recent use of 3D printers, nanotechnology, cell phones, augmented reality in science classrooms and their effects on science teachers have made the study more interesting and increased the importance of the study. Here, the study was limited to middle school science teachers. Therefore, the aim of the study is to examine the recent trends of the articles on TPACK and technology integration of secondary school science teachers in Türkiye in terms of subject, year of publication, methodology, journal of publication, and salient results of the studies. This study provides suggestions for the development of technological pedagogical content knowledge of secondary school science teachers in Türkiye and the content, methods, and results of teacher training programs. It is thought that this study will shed light on future research in this field. Because, thanks to the content analysis on TPACK for science teachers, researchers will be able to look at this field holistically, such as where there are deficiencies, which purposes and methods have been studied more, which ones have been studied less, what are the remarkable results of the research, and construct their research accordingly. This study will give a big clue to see the big picture. This case reveals the importance of this study. Within the scope of the research, answers to the following questions about TPACK for science teachers in Türkiye were sought:

1. What is the purpose of the studies?
2. In which years were the studies conducted?
3. In which journals were the studies published?
4. Which method was used in the studies?
5. Which sample selection was preferred in the studies?
6. What are the data collection tools used in the studies?

7. What are the data analysis methods used in the studies?
8. What kind of results were obtained in the studies?

Method

Model

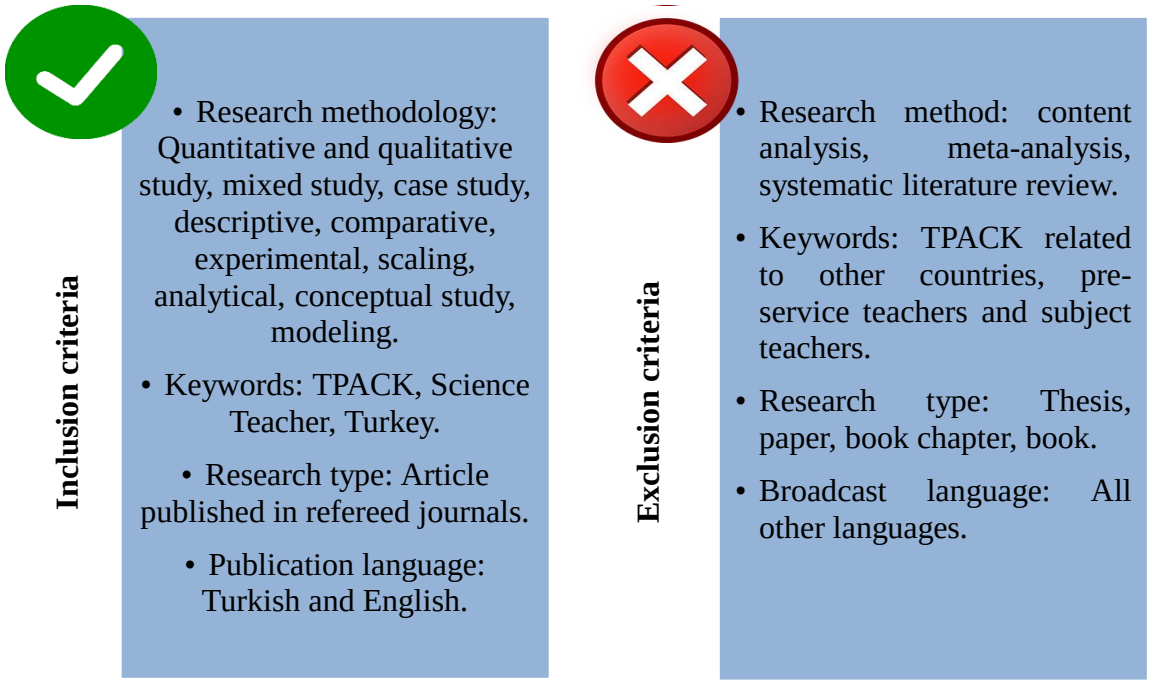
In this study, "systematic literature review" was used as appropriate for the purpose. A systematic literature review is a comprehensive synthesis of a large number of studies conducted for transparency and accountability to reveal important connections and patterns of studies in a subject or field. Systematic literature review is a scientific process and will shed light on future educational research (Dixon-Woods, 2011; Minner, Levuy & Century, 2010). In accordance with the method of the research, firstly, the criteria for selecting scientific publications were determined by the screening method and screening was carried out. The data obtained as a result of screening were included in the analysis process (Karaçam, 2013).

Data Collection Tools

In this study, secondary data analysis was used as a data collection method. Secondary data analysis is the process of using and analyzing the data previously collected for another research or study (Yıldırım & Şimşek, 2013). In this context, "Technological pedagogical content knowledge" or "TPACK" and "Science Teacher" from Web of Science, EBSCOHOST and GOOGLE ACADEMIC databases including Türkiye index, "Technological pedagogical content knowledge" or "TPACK" and "Science Teacher" and “Türkiye” and "Technological pedagogical content knowledge" or “TPACK” and "Science Teacher" and “Türkiye” were used as keywords. Since TPACK-related research was introduced to the literature in 2005, the date in the search criteria was limited to 2005-2023. The criteria for the inclusion and exclusion of studies in the systematic literature review are presented in Figure 1.

Figure 1

Inclusion and Exclusion Criteria



According to the criteria determined as a result of Figure 1, quantitative, qualitative and mixed methods studies were selected. In addition, the research is limited to TPACK for science teachers in Türkiye. It was paid attention that the scientific studies should be articles published in refereed journals and the language should be Turkish or English. As a result of the search within these criteria, 21 scientific articles were reached.

Collection of Data and Analysis

In the study, the collected data were analyzed by content analysis method. Content analysis is an analysis technique used to identify and make sense of concepts and themes in texts (Yıldırım & Şimşek, 2013). The data obtained from the literature review were coded and analyzed within the framework of themes and subheadings determined in line with the aims of the study. Through this analysis, percentages and frequencies were used to analyze the trends of the articles published on technological pedagogy on secondary school science teachers in Türkiye in terms of purpose, year of publication, journal, method, sample selection, data collection tools, data analysis, and salient results of the studies.

Findings

A total of 21 academic articles on technological pedagogical content competencies of secondary school science teachers were accessed. In this context, the frequency distribution of the main purposes of the articles analyzed in the study is presented in Table 1.

Table 1

Data on the Main Purposes of Articles Published for Secondary School Science Teachers

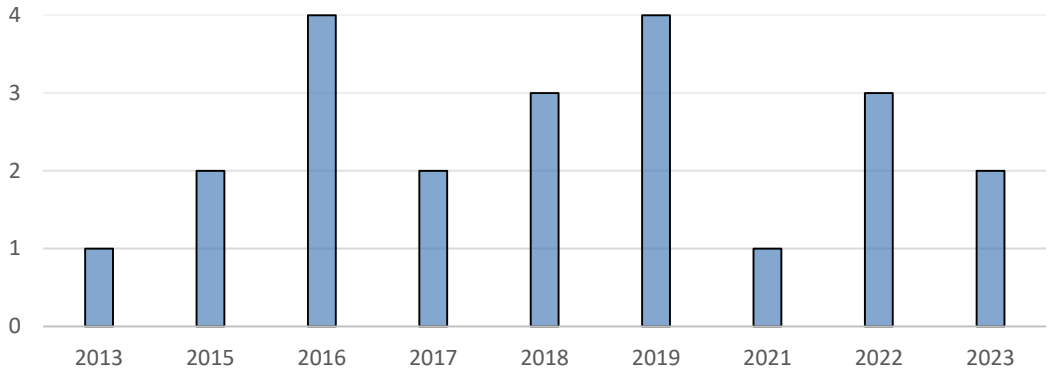
Objective	**f**
Determining TPACK levels and examining them in terms of various variables.	5
Examining the thoughts/competencies/levels about TPACK.	4
Revealing other dimensions related to TPACK according to the structural equation model.	3
Determining TPACK self-confidence levels and examining them in terms of various variables.	3
Examining TPACK development through argumentation.	3
To adapt the TPACK scale/survey into Turkish and test its validity and reliability.	1
Examining TPACK self-confidence perceptions.	1
Examining the effect of in-service training courses on TPACK self-confidence development.	1
Examining the effect of the program prepared for gaining TPACK on self-efficacy levels towards TPACK.	1
Determining the extent to which (TPACK) is effective in individual teaching processes by addressing the context/environment in which they are located.	1
Determining to what extent TPACK is effective in individual teaching processes.	1

According to Table 1, it is seen that the purpose of a significant part of the analyzed studies is "Determining TPACK levels and examining them in terms of various variables and examining thoughts/competencies/levels about TPACK". After that, it was determined that the highest objectives were "revealing other dimensions related to TPACK according to the structural equation model", "determining TPACK self-confidence levels and examining them in terms of various variables" and "examining TPACK development through argumentation". It was determined that there was 1 study on other objectives.

The numerical distribution of the articles published in Türkiye on technological pedagogical content knowledge of secondary school science teachers according to years is presented in Graph 1.

Graph 1

Numerical Distribution of Science Teachers' Articles on TPACK According to Years



When Graph 1 is examined, it is determined that the studies on technological pedagogical content knowledge and technology integration of secondary school science teachers in Türkiye started in 2013, with the highest number of studies in 2016 and 2019, 3 studies in 2018 and 2022, 2 studies in 2015, 2017 and 2023, and 1 study in 2013 and 2021.

The numerical distribution of articles on technological pedagogical content knowledge of secondary school science teachers in Türkiye according to the journals in which they were published is presented in Table 2.

Table 2

Distribution of Studies according to the Journals in which They Were Published

Published in Journal	**f**
"Education and Science"	2
"Education and Information Technologies"	2
"Gazi University Journal of Gazi Educational Faculty"	2
"Ahi Evran University Journal of Kırşehir Education Faculty"	1
"Journal of Social Sciences of Mus Alparslan University"	1
"Educational Academic Research"	1
"Journal of Educational Technology Theory and Practice"	1
"European Journal of Education Studies"	1
"International Journal of Human Sciences"	1
"Elementary Education Online"	1
"Journal of Social and Humanities Sciences Research"	1
"The Journal of Theoretical Educational Science"	1
"Necatibey Faculty of Education, Electronic Journal of Science and Mathematics Education"	1
"Trakya University Journal of Social"	1
"The Journal of Turkish Educational Sciences"	1
"Turkish Scientific Researches Journal"	1
"Journal of Uludag University Faculty of Education"	1
"VanYüzüncü Yıl University Journal of Education"	1

When Table 2 is examined, it is determined that the articles on technological pedagogical content knowledge of secondary school science teachers in Türkiye were mostly published in "Education and Science", "Education and Information Technologies" and "Gazi University Journal of Gazi Educational Faculty" journals, respectively. In other journals, only 1 study was published about the field in question. The distribution of the studies varies according to the journals in which they were published.

Table 3 presents the numerical distribution of the articles published in Türkiye on TPACK knowledge of secondary school science teachers according to their methods.

Table 3

Distribution of Studies According to Methods

Method	**f**	**%**
Quantitative: Survey (9), experimental (3), scale adaptation and development (1), modeling (1)	14	66.7
Mixed	5	23.8
Qualitative: Case study (2)	2	9.5

According to Table 3, the most frequently preferred methods in the 21 studies were quantitative, mixed and qualitative research methods, respectively. In quantitative research methods, survey and experimental methods were mostly used.

Table 4 presents the distribution of the articles published in Türkiye on secondary school science teachers' TPACK according to the sample selection.

Table 4

Distribution of Articles According to Sample Selection

Sample selection	**f**
Convenience sampling	9
Purposive sampling	8
Simple random sampling	2
Cluster sampling	2
Stratification sampling	1

According to Table 4, it was determined that the most frequently preferred sample selection in the 21 studies examined were convenience sampling, purposive sampling, simple random sampling, cluster sampling, and stratification sampling, respectively.

Table 5 presents the distribution of articles published in Türkiye on technological pedagogical content knowledge of secondary school science teachers according to data collection tools.

Table 5

Distribution of Articles According to Data Collection Tools

Data collection tools	**f**
Scale	16
Interview form	6
Survey	1
Achievement test	1
Open-ended questions	1
Observation form	1
Evaluation form	1

According to Table 5, it was determined that the most frequently preferred data collection tools in the 21 studies examined were scale and interview form, respectively. In addition, questionnaires, achievement tests, open-ended questions, observation, and evaluation forms were used to collect data.

Table 6 presents the distribution of the published articles on technological pedagogical content knowledge of secondary school science teachers in Türkiye according to data analysis.

Table 6

Distribution of Articles According to Data Analysis

Data Analysis		**f**
Predictive (31)	Anova-Ancova	13
	t-testi	8
	Non-parametric analysis	5
	Correlation	2
	Structural equation modeling	2
	Regression	1
Qualitative (11)	Content analysis	8
	Qualitative descriptive	3
Descriptive (6)	Percentage and frequency	4
	Measures of central tendency	2

When Table 6 is examined, it is determined that the most frequently used analysis in the articles published in Türkiye on technological pedagogical content knowledge of secondary school science teachers is Anova-Ancova, one of the predictive analysis methods. In addition, t-test, one of the predictive analysis methods, content analysis, one of the qualitative analysis methods, and percentage and frequency, one of the descriptive analysis methods, are other frequently used analysis methods.

The remarkable results of the articles published in Türkiye on technological pedagogical content knowledge of secondary school science teachers are presented in Table 7.

When Table 7 is examined, among the remarkable results of the studies conducted with TPACK for secondary school science teachers in Türkiye; TPACK levels of teachers are high (f:5), there is no significant difference between TPACK self-confidence and gender (f:4), educational status (f:2), branch (f:2), there is a significant difference between TPACK and TPACK self-efficacy and gender (f: 2), between TPACK and TPACK self-efficacy and gender (f: 2), between TPACK and professional experience (f: 2), between TPACK self-confidence and length of service, frequency of technology use, in-service and training on educational technologies (f: 2), and there is a positive relationship between TPACK and TPACK competencies and technology attitudes. In addition, other results of the study are less common.

Table 7

Noteworthy Results of the Published Males on Technological Pedagogical Content Knowledge

Category	Results	f
Quantitative study: There is a significant difference	"There is a significant difference between TPACK and TPACK self-efficacy and gender".	2
	"There is a significant difference between TPACK and professional experience."	2
	"There is a significant difference between TPACK self-confidence and length of service, frequency of technology use, in-service and training on educational technologies."	2
	"There is a significant difference between TPACK and educational status, branch, school type, working place, availability of interactive whiteboard, computer, interactive whiteboard and other instructional technology usage competence and usage time, participation in interactive whiteboard usage course."	1
	"There is a significant difference between TPACK self-confidence levels, and the type of faculty graduated from, branch, access to technology, average daily computer usage time, adequacy of the education given in the university on instructional technologies, voluntary participation in in-service training."	1
	"There is a significant difference between TPACK and branch and length of service."	1
	"TPACK development was realized through argumentation."	1
	"Content Knowledge (CK), Technological Pedagogical Knowledge (TPK) and	1

	Pedagogical Content Knowledge (PCK) have direct and positive effects on TPACK."	
	"While the educational practices aimed at gaining TPACK had a statistically significant positive effect on self-efficacy towards TPACK, it did not have a statistically significant effect on retention."	1
Quantitative study: There is not a significant difference	"There is no significant difference between TPACK self-confidence and gender."	4
	"There is no significant difference between TPACK self-confidence and educational status and branch."	2
	"There is no significant difference between TPACK and educational status, length of service, institution of employment, taking technology course and gender."	1
	"There is no significant difference between TPACK self-confidence and school type, having a tablet, institution of employment, attending a technological training, receiving in-service training online or face-to-face."	1
	"There is no significant difference between TPACK self-confidence and gender."	1
	"There is no significant difference between TPACK self-confidence and educational status and branch."	1
	"There is no significant difference between TPACK and educational status, length of service, institution, taking technology course and gender."	1
	"There is no significant difference between TPACK self-confidence and school type, having a tablet, institution of employment, attending a technological training, receiving in-service training online or face-to-face."	1
Survey and Qualitative Studies	"Teachers' TPACK levels are high."	5
	"Teachers' TPACK self-confidence levels and self-efficacy beliefs are high. "	1
	"Teachers' TPACK self-confidence levels are above the middle level."	1
	"Teachers have opinions about supporting the use of technological, field, and pedagogical knowledge together."	1
	"Teachers consider themselves competent in ethics, application, design, and specialization sub-dimensions of techno pedagogical education competence scale."	1
	"Teachers perform differently in different subject areas in terms of teaching practices with technology."	1
	"Teachers' use of TPACK-based argumentation practices in lessons is successful.	1
	Some of the teachers have difficulty in adapting to the technology."	1
	"TPACK is directly/indirectly affected by professional development, teachers' beliefs and attitudes, administrative support, student influence, technological infrastructure and support, colleague interaction, educational technology experience and lack of time."	1
	"It provides evidence that TPACK-based argumentation training positively affects science teachers' general understanding of scientific knowledge and their understanding of scientific knowledge in the themes of hypothesis commitment, justification, and reliability."	1
	"Teachers lack knowledge about TPACK."	1
	"Teachers perform differently in different subject areas in terms of teaching practices with technology."	1
Relational Survey	"There is a positive relationship between TPACK and TPACK competencies and technology attitudes."	2
	"There is a positive relationship between TPACK self-efficacy and access to instructional	1
	"technologies, frequency of use, adequacy of the education given in the university on instructional technologies, and the status of receiving education."	
The Scale	"A reliable TPACK scale adaptation was developed for secondary school teachers."	1

Discussion and Results

Today, technology has an impact in every field including education. Especially the need for technological tools such as computers, interactive whiteboards, printers, and augmented realities used in the field of education has gradually increased. The increase in technological tools in the educational environment has revealed the need for their use. In this

respect, Technological Pedagogical Content Knowledge (TPACK) has become one of the most important characteristics that teachers should have (Korucu, Usta & Atun, 2017). Therefore, in this study, studies on the technological pedagogical content competencies of secondary school science teachers in Türkiye were examined in terms of the year of publication, the journal in which it was published, method, sample selection, data collection tools, data analysis and the remarkable results of the studies. It is thought that understanding the trends of recent studies conducted with science teachers on TPACK will both guide new researchers, be a source of data, and contribute to the effective dissemination of technology use in education.

Among the aims of the studies on technological pedagogical content knowledge and technology integration of secondary school science teachers in Türkiye, it is determined that the most important aim is to determine the status of teachers in terms of TPACK and to examine them in terms of various variables. After this purpose, the most common aims are to reveal the dimensions of teachers' TPACK and the relationship between the dimensions according to the structural equation model, and to examine the development of TPACK with the method based on Argumentations, in-service training or applications. There are also results parallel to these findings in the literature (Devran, Öztay & Tarkın-Çelikkıran, 2021; Dikmen & Demirer, 2016; Kaleli Yılmaz, 2015). When the articles on TPACK for science teachers in Türkiye are examined, it is seen that the data are collected and analyzed from teachers in a short time with a few measurement tools. The most used method in the articles is survey. Therefore, conducting a large number of survey studies for science teachers and having similar objectives and sample groups may not contribute much to the field. It is thought that it is more important to conduct such studies with many types and numbers of data collection tools in a long process, to examine the TPACK development of science teachers, to examine the decrease or increase in TPACKs, and to reveal what science teachers experience in the process by collecting qualitative data.

In Türkiye, studies on technological pedagogical content knowledge and technology integration of secondary school science teachers started in 2013. It was determined that the most studies related to the field were conducted in 2016 and 2019. Although the year 2023 has not yet been completed, it is seen that there are 2 studies. The fact that there were no studies in 2020 and only one study in 2021 may be due to the negative effect of covid 19. On the other hand, the fact that there are 3 studies in 2022 and 2 studies in 2023, despite the fact that it has not yet been completed, may give the impression that the study on the field will

increase in recent years. Korucu, Usta & Atun (2017) examined the trends of studies on technological pedagogical content knowledge. As a result of the research, it was stated that the studies have increased over the years. In Yıldızay & Çetin's (2019) content analysis of studies on the use of educational technologies in science education, it was determined that these studies started in 2010 and increased significantly in 2013-2017. In Saykal & Uluçınar Sağır's (2021) content analysis study on teacher competencies and TPACK in Türkiye, it was stated that the most studies were conducted in 2015 and 2019. In the literature, there are also studies on the increase in the number of studies on TPACK over the years (Devran, Öztay & Tarkın-Çelikkıran, 2021; Dikmen & Demirer, 2016; Rosenberg & Koehler, 2015).

It was determined that the articles on teachers' technological pedagogical content knowledge were mostly published in "Education and Science", "Education and Information Technologies" and "Gazi University Journal of Gazi Educational Faculty", respectively. It was determined that TPACK studies on teachers were published in different journals. Articles published in other journals are less common. In Dikmen and Demirer's (2016) study on determining TPACK tendencies in Türkiye, TPACK studies were published in "Education and Science", "International Journal of Human Sciences", "Necatibey Faculty of Education, Electronic Journal of Science and Mathematics Education", "Elementary Education Online" and "Ahi Evran University Journal of Kırşehir Education Faculty".

In TPACK articles for secondary school science teachers in Türkiye, the most frequently preferred methods are quantitative, mixed, and qualitative research methods, respectively. In quantitative research methods, survey and experimental methods were mostly used. The most frequently preferred sample selection is convenience sampling. This is followed by purposive sampling, simple random sampling, cluster sampling and stratification sampling. It was determined that the most preferred data collection tool was scale. The use of scales in the studies may be an indication that the studies were conducted with quantitative methods. In the studies, data were also collected mostly by interview form, achievement test, open-ended questions, observation, and evaluation form, respectively. There are studies similar to this result in the literature (Dikmen & Demirer, 2016; Korucu, Usta & Atun, 2017; Yıldızay & Çetin, 2019). On the other hand, in Devran, Öztay & Tarkın-Çelikkıran's (2021) study on TPACK, it was determined that the most frequently used methods were qualitative, quantitative, and mixed, the most frequently used data collection tools were questionnaire/scale, interview and observation, and the most frequently used sample selection was purposive and convenience sampling. In Saykal & Uluçınar Sağır's (2021) content

analysis study on teacher competencies and TPACK in Türkiye, it was stated that the most frequently used methods were quantitative, qualitative, and mixed, and the most frequently used data collection tools were scale, questionnaire, interview/interview. In this study, when the method, sample selection and data collection tool of TPACK studies for science teachers are taken into consideration, it is aimed to reveal the process as it exists and to examine it with various variables instead of observing the change in the process. However, the frequency of using experimental methods, case, and action research in which changes in the process are observed is extremely low. Therefore, the use of both quantitative and qualitative studies can increase the quality of the studies more.

It was determined that the mos Türkiye was Anova-Ancova, one of the predictive analysis methods. In addition, t-test among predictive analysis methods, content analysis among qualitative analysis methods, and percentage and frequency among descriptive analysis methods are other frequently used analysis methods. In Dikmen and Demirer's (2016) study on the determination of TPACK dispositions in Türkiye, the most frequently used analyses in the study were descriptive and predictive analysis from quantitative analysis, and content and descriptive analysis from qualitative research, respectively. Devran, Öztay & Tarkın-Çelikkıran (2021) stated that the most frequently used analyses in their study on TPACK were content analysis, t-test, Anova, descriptive analysis, frequency percentage and nonparametric tests.

The above trends also emphasize the increasingly technological nature of science education. Science teaching and learning in secondary school classrooms in our country is known to be driven more than ever by modern technologies that also shape how teachers experience the natural or physical world (Verbeek, 2001). As "naked" perception (human-world) gives way to mediated perception (human-technology-world), increasingly, students' and teachers' scientific perceptions and understandings are increasingly populated by technologies that mediate, enrich and simulate the natural world. Science educators ensure that students see technological tools as transparent and unbiased instruments that simply "show the reality that exists" and reveal what is "really" there (e.g., telescopes, microscopes). In addition, people try to understand and master nature through direct engagement with technology itself (e.g., robots, automated machines). Instead of humans relating to the world through technology, nature relates only to technology itself, imperceptibly, relegating human experience to the background.

The literature reviewed above also suggests that the field of science education will in the future focus exclusively on the pedagogical aspects of technology (cognitive processes and conceptual issues). Regarding the pedagogical use of technology, science education researchers have prioritized conceptualization, focusing on issues related to students' cognitive development and using modern technologies effectively to encourage students to acquire more sophisticated understandings of science. A shortcoming of the research is that much less attention has been paid to the sociocultural aspects of technological innovations in science classrooms with increasing technological advances, such as the impact of technological innovations on existing school culture or the emergence of new identities, cultural values, and interactional processes in the science classroom.

Among the noteworthy results of the studies conducted with TPACK for secondary school science teachers in Türkiye; it was determined that teachers' TPACK levels were high, there was no significant difference between TPACK self-confidence and gender, educational status and branch, there was a significant difference between TPACK and TPACK self-efficacy and gender, between TPACK and professional experience, between TPACK self-confidence and length of service, frequency of technology use, in-service and training on educational technologies, and there was a positive relationship between TPACK and TPACK competencies and technology attitudes. In addition, other results of the study are less common. In the study, TPACK levels of science teachers were found to be high at most. However, Kaya & Kaya (2013) stated that only applying a scale to individuals related to TPACK will reveal not their TPACK but their perceived or thought knowledge, self-confidence and competence levels related to TPACK. Therefore, it can be said that examining lesson plans, conducting interviews and observations in addition to quantitative methods and data in TPACK studies for science teachers will increase the quality of the studies more. Teachers can learn technology, but they are limited in putting what they have learned into practice (Jen, Yeh, Hsu, Wu & Chen, 2016). Therefore, teachers should be trained in the practical application of technology rather than theoretical training.

In this study, TPACK studies for science teachers were systematically examined by content analysis and a holistic evaluation was made in this way. A content analysis study conducted in a certain field provides researchers with the opportunity to look at it from a holistic perspective. Thanks to the analysis of TPACK studies for science teachers, it is possible to obtain information about this field, to determine the positive, strong, deficient, and weak aspects of scientific publications and to evaluate the performance of publications.

Recommendations

It is recommended that quantitative and qualitative methods should be used together in the studies on science teachers and that the studies should be carried out over a long period of time in order to monitor the process by collecting a large number and variety of qualitative data. In this way, the real TPACKs of science teachers can be determined and their TPACK development can be monitored.

It is recommended to implement educational contents that will support the TPACK development of science teachers in the Faculties of Education before they graduate and to support the TPACK development of science teachers with in-service training.

It is recommended to conduct scientific studies that examine the TPACK development of science teachers and support their TPACK development and to increase the number of these studies.

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