Available online at http://www.bedujournal.com/

BASE FOR ELECTRONIC EDUCATIONAL SCIENCES

ISSN: 2718-0107

Base for Electronic Educational Sciences, 5(2), 97-118; 2024

Investigation of Secondary School Mathematics Teacher Candidates' Technological Pedagogical Content Knowledge and Information Technology Use through Online Photovoice Method

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APA Citation:
Koç Koca, A. (2024). Investigation of secondary school mathematics teacher candidates' technological pedagogical content knowledge and information technology use through online photovoice method. *Base for Electronic Educational Sciences, 5*(2), 97-118.
Submission Date: 08/06/2024
Acceptance Date: 30/07/2024

Abstract

In this study, the areas that pre-service mathematics teachers associate with their use of information technology and their Technological Pedagogical Content Knowledge (TPACK) were examined. In this qualitative study, data were collected from 98 pre-service mathematics teachers using the Online Photovoice (OPV) method. In the analysis of the data, Online Interpretative Phenomenological Analysis (OIPA) was used to examine pre-service teachers' information technology uses and TPACK separately with a holistic approach. Information technology usage and demographic characteristics of the participants were examined in line with the data obtained through OPV. As a result of the analysis, it was found that the participants were able to use computers at an intermediate level, very few of them were able to receive expert support. They used technology frequently and used social networking sites the most. The data obtained for TPACK were analyzed in three stages by the researcher and a mathematics education specialist. As a result of the analysis, 13 different main themes emerged. It was determined that mathematics teachers mostly expressed TPACK with main themes such as life, knowledge increase, concretization, and education. On the other hand, it was determined that the participants associated TPACK mostly with the microsystem elements of the ecological systems theory and the effect of this association decreased as the system expanded.

Keywords: Pre-service mathematics teachers, Online Photovoice (OPV), Technological Pedagogical Content Knowledge (TPACK), Information technologies.

Introduction

Technology integration has become one of the important components of effective education today. The inclusion of technology, which is in constant change and transformation, in educational processes also changes the standards of the teaching profession (Başaran et al., 2021). Especially today, the establishment of technological pedagogical content knowledge in education has led to a move away from traditional learning environments. Thus, not only students' access to information but also the development of many skills with the help of information technologies has become a goal in education. Therefore, in order to develop students' knowledge and skills, teachers need to have knowledge of the basic concepts, tools and structures of the field and the integration of the content to be taught with technology (Yiğit Gençten et al., 2022). Technology integration in integrated education environments improves pedagogical practices and provides students with high-level learning skills (Keengwe & Onchwari, 2011; Yiğit Gençten & Aydemir, 2023).

Teachers' effective integration of technology into the teaching and learning process increases students' motivation, academic achievement and attitudes towards learning (Golezani & Gülcü, 2021). Looking at the studies conducted especially in mathematics discipline, it is seen that students generally do not like mathematics and are afraid of mathematics (Koç Koca, 2023). In order to avoid negative situations that arise in teaching, teachers could include more educational entertainment during their teaching. Including more educational entertainment in the course increases student motivation and improves their adaptation to the course. It will be inevitable for motivated students to comprehend the course content and improve their mathematical skills. Studies show that with the help of technology, teachers make the abstract structure of mathematics concrete and contribute to making mathematics meaningful for students (Hannafin et al., 2001). Therefore, teachers need to have a certain level of technological competence within the scope of technology.

In order to ensure effective integration of technology knowledge into the learning process, the contributions and limitations of the selected technological tools and materials to the learning process should be evaluated in line with pedagogical approaches. Considering the frequent use of information and communication technologies today, they should be transferred to the learning process according to the individual interest, characteristics, level and needs of the student. In this respect, the integration of Web 2.0 applications (blogs, podcasts, wikis, social networks, etc.) into educational environments where users can generate their own ideas without being computer literate is an important step in providing students with skills. This contributes to more frequent and real-time collaboration of users in terms of information and ideas (Song, 2010). This is one of the important steps that enable the development of learning and teaching environments in the fields of education and training (Wright & Akgündüz, 2018).

The pedagogical use of technology is strongly influenced by the content to be taught (Graham et al., 2012). For this reason, the ways of using technology in different content areas vary. In terms of mathematics education, uses such as spreadsheets and function preparation for computer algebra systems stand out. In the field of dynamic geometry, software such as Skechpad and GeoGebra are used. Thus, all possible

assumptions of the points forming a drawn geometric shape under translational motion can be concretized. This concretization is important in mathematics education. In addition, these software programs provide students with flexible spaces for problem solving and contribute to students' algebraic and spatial thinking skills. The development of algebraic and spatial thinking skills allows students to solve the same problem with different methods over time. This is one of the ultimate goals to be developed in students through mathematics education.

Technology should be supported by content knowledge and domain-specific pedagogical methodology. In current practices, it is seen that pre-service mathematics teachers focus on teaching technology instead of teaching with technology. However, considering technology independently from pedagogical content knowledge may cause pre-service mathematics teachers to fail to emphasize the complexity of technology integration knowledge. For this reason, environments where pre-service teachers can actively use their Technological Pedagogical Content Knowledge (TPACK) in their learning processes should be provided. Thus, pre-service teachers can be enabled to combine the critical relations of the field with other fields with curricula and subject area.

Considering that the person who directs and guides the education and training process is the teacher, it is a requirement of professional development that teachers adapt to the modern time developments and changes. The qualifications expected from teachers in contemporary education have become more diversified with the increasing use of technology in education. For this reason, there is a need for applications and researches in teacher training programs to ensure the development of effective technology-integrated knowledge of prospective teachers in accordance with the interests and expectations of students.

Studies show that mathematics teachers cannot use technology in their lessons with the expected competence, level and purpose (Avcı & Coskuntuncel, 2019; Crompton, 2015; Karim & Zoker, 2023). In the studies conducted with pre-service mathematics teachers, similar situations were observed and it was determined that pre-service teachers could not prepare complex and multi-purpose materials with the help of technology (Çelik Kaya, 2023; Niess, 2012). However, technology integration in mathematics education is considered very important in terms of content, techniques, and methods (Ivy, 2011). In addition, when the literature was examined, it was found that there were a limited number of studies examining the areas that pre-service mathematics teachers associate their Technological Pedagogical Content Knowledge (TPACK) with (Ardıç, 2021; Marbán & Sintema, 2021). For this reason, there is a need for studies to determine and improve the competencies of pre-service mathematics teachers in the field of information technologies and pedagogy, which are of critical importance in the education system. In this study, it was aimed to examine the areas that pre-service mathematics teachers associate with TPACK and how they use information technologies.

It was found that most of the studies used quantitative methods (Karim & Zoker, 2023; Marbán & Sintema, 2021), while none of the studies using qualitative research methods used Online Photovoice (OPV; Tanhan, 2020; Tanhan & Starck, 2020) and Online Interpretative Phenomenological Analysis (OIPA). OIPA was to analyze the data collected with OPV (Tanhan, 2020; Tanhan & Starck, 2020). OPV and/or OIPA have been used in many

different subjects and very effective findings have been obtained, some of these studies are as follows: mental health during COVID-19 (Armiyau et al., 2022; Tanhan et al., 2021), dynamics that facilitate and complicate couples' relationship (Genç et al., 2023), understanding online and distance education (Doyumğaç et al., 2021), women's view of their sexuality (Ozkan & Tanhan, 2023), and understanding mathematics perception (Koç Koca, 2023).

It was decided to use OPV in this study because it offers a different perspective on human experiences and allows reaching more people and removing time-space constraints, unlike many other qualitative methods (e.g., traditional photovoice). Thus, the investigations on pre-service mathematics teachers' technological pedagogical content knowledge and their use of information technologies were carried out using OPV. It is thought that the results obtained by using OPV in the study will contribute to the literature on pre-service mathematics teachers' integration of information technologies into education, their ability to associate pedagogical processes with technology, their use of information technologies, and thus their TPACK competencies.

Method

In this study, Online Photovoice method, one of the current and innovative qualitative research methods, was utilized. OPV is a phenomenological qualitative research method that enables the researchers to understand an existing situation from the perspectives of the participants as much as possible. The views of pre-service teachers on TPACK obtained using the OPV method were analyzed using Online Interpretative Phenomenological Analysis (OIPA; Tanhan, 2020; Tanhan & Strack, 2020). In addition, the information technology usage and demographic characteristics of the participants were examined in line with the data obtained from the OPV. Thus, it was aimed to obtain the real thoughts that emerged in the minds of the participants about the subject.

Online Photovoice

Photovoice is a research method that enables individuals to express themselves from different perspectives by combining words and images. This method also utilizes the power of photographs to help the reader understand events through the eyes of the person living those events (Palibroda et al., 2009; Tanhan & Strack, 2020). Although many lived experiences can be observed from the outside, it is difficult to understand situations where mental skills such as pedagogical content knowledge are transferred using mental skills. For this reason, methods such as photovoice help people to understand phenomena and events in depth.

There are two variants of this method: traditional and online. In the traditional photovoice method, applications are carried out in groups and face-to-face. Small groups that come together receive a short method training from the researchers (Tanhan, 2020; Tanhan & Strack, 2020). After the training, people take photographs that reflect their own experiences on the subject and explain them with the help of words. Thus, the participants have the opportunity to explain the situation by being aware of their strengths through both photographs and their own expressions (Tanhan & Strack, 2020). Traditional photovoice has its limitations (Tanhan, 2020). Some of these limitations are that the participants need to be together in the same place and at the same time,

and that they are restricted because they express themselves in a group. On the other hand, this situation prevents the participants from remaining anonymous and requires the study to be carried out in a physical place and planned time.

OPV is an innovative methodology developed by Tanhan and Strack (2020) to turn the limitations of the traditional method into advantages. This method allows participants to come together in online environments and express themselves freely, especially during periods such as the pandemic, which severely restricts social life. Unlike the traditional method, it enables reaching a much larger number and diverse participants as it is carried out in online environments. In addition, conducting a study in online environments allows people to easily participate in the study in the environments and times they feel good, without feeling pressure. This helps the participants to convey what they want to convey as they are. For this reason, the OPV method, which is inspired by traditional photovoice, overcomes the main problems of traditional methods in terms of confidentiality, cost, number of participants and time-space variables. On the other hand, the use of Online Interpretative Phenomenological Analysis (OIPA) in the analysis of the data obtained regarding TPACK ensures that what the participants want to convey is obtained and analyzed as it is.

Online Interpretative Phenomenological Analysis (OIPA)

OIPA (Tanhan, 2020; Tanhan & Strack, 2020) is a data analysis method built on traditional Interpretative Phenomenological Analysis (IPA). OIPA was developed specifically to analyze the data collected through OPV. In traditional IPA, researchers seek opinions from participants through face-to-face interviews or pre-prepared questionnaires and try to derive meaning and themes from the data (Brunsden & Goatcher, 2007; Tanhan, 2020; Tanhan & Strack, 2020). However, Tanhan (2020) and Tanhan and Strack (2020) stated that this situation is not objective and functional enough (e.g., loss of time, increase in cost, loss of the participant's perspective) and that data loss may occur in these methods. In addition, the increase in the number of participants in the study causes the data collection and analysis process to be much longer. OIPA allows for the elimination of such limitations. Being online allows reaching a large number of participants and allows participants to create the main themes of their shared stories. OIPA can be used to collect and analyze data alone (Kızılay, 2022; Koç Koca, 2023; Tanhan, 2020; Tanhan & Strack, 2020; Subaşı, 2023) or it can be used to analyze data collected with OPV (Doyumğaç et al., 2021; Öğülmüş et al., 2021; Subasi et al., 2023; Tanhan, 2022; Tanhan & Strack, 2020; Tanhan et al., 2021; Tümkaya et al., 2021), as it is done in the current research.

Participants

Since the research aims to collect data from a group with certain qualifications, the participants of the research were determined by purposive sampling method. Purposive sampling is based on suitability for the purpose, and data are collected from the sampling units that are thought to contribute best to the research (Yıldırım & Şimşek, 2013). Thus, selecting data-rich situations and conducting in-depth research by adhering to the purpose of the study becomes a priority (Patton, 1997). Considering the aforementioned qualifications, the study was conducted with pre-service teachers studying in the Department of Elementary

Mathematics Teaching. In the study, an online data collection tool created through "Google Forms" was sent to pre-service teachers at all grade levels. It was seen that 102 pre-service teachers between the ages of 20-25 studying in the 2nd and 3rd classes participated in the study; four participants did not allow the use of the information they declared. Thus, the data obtained from 98 pre-service teachers (68 female, 30 male) who voluntarily participated in the study were analyzed.

Data Collection Tools

Since this study aimed to examine the areas that pre-service mathematics teachers associate with TPACK and their use of information technologies, the data were obtained by following the OPV form and the SHOWED *(GÖZSAN in Turkish)* questions in the form. Before the data were collected, online interviews were conducted with the pre-service teachers who were planned to participate in the study and the aims of the study were explained.

In the data collection process, the OPV form, which was prepared by the researcher and finalized by two mathematics education experts, was used. The OPV form was prepared in two parts: Demographic Information and Information Technology Use (Part 1) and Understanding the Technological Pedagogical Content Knowledge of Prospective Elementary Mathematics Teachers through OPV (Part 2).

In the first part, information on the demographic characteristics and information technology use of pre-service teachers was collected. Thus, information on the demographic characteristics of the pre-service teachers such as gender, age, grade level, income level was obtained. Their level of informatics was examined with the help of titles such as their own statements, whether they received training from a course or an expert, their daily technology usage time, and which of the Web 2.0 Applications of Information Technology in Education they use.

In the second part, pre-service teachers' Technological Pedagogical Content Knowledge (TPACK) was examined by following the following steps of OPV.

Step 1 - First Words/Concepts that Come to Your Mind: At this stage, pre-service teachers are asked to express (using 1-10 words) the first word or words that come to their minds when they think about the title "Technological Pedagogical Content Knowledge".

Step 2 - Photo Uploading: At this stage, the pre-service teachers were asked to think a little more about the word or words that define, symbolize and describe "Technological Pedagogical Content Knowledge." Then they were asked to take a representative photograph to depict one or more of these most important words. At this stage, the participants were left free to take as many photographs as they wanted and to use the photographs they had taken before if they were suitable for this study or to make use of any other ready-made images.

Step 3 - Adding a Story - Creating a Whole Meaningful Paragraph/Story Including the SHOWED Questions: At this stage, participants were asked to add a story to the photograph they took. Thus, with the story written, the photograph came to life and became understandable by everyone. Participants were also advised to make use of the following SHOWED questions in order to make their stories more

meaningful and inclusive. In this way, people other than the participant could have the opportunity to understand the participant's perspective as it is and the story in his/her words.

S. What do you ***S*****EE** in the photograph related to the topic "Technological Pedagogical Content Knowledge"?

H. What is ***H*****APPENING** in the photo (briefly describe/describe the photo)?

O. How does what is happening in the photograph relate to **Y*O*U**?

W. ***W*****HAT** is it that creates or causes this situation?

E. What are you ***E***XPERIENCING (bodily sensation, emotion, thought, behavior) when you took the photo and now when you are writing this?

D. When you think about all these including the first words come to your mind, the photo, and especially the comment/story you shared about "Technological Pedagogical Content Knowledge", what/what can we all ***D*****O** as educators to make life more meaningful?

Step 4: Summary Words: Please Use At Least 3 Summary Word Groups and No More Than 10 Word Groups (e.g., "Technology is related to life" is a Word Group): At this stage, the participants were asked to write at least one and at most three word groups to summarize their stories and photos. Thus, instead of the researcher, the participants were enabled to create themes according to their own perspectives. During the analysis, the main themes were created by looking at the participant's summary words in this fourth step. And this fourth step formed the basis of the OIPA used in the data analysis, as explained below.

Step 5 - Attributing "Technological Pedagogical Content Knowledge" to the Levels of Ecological Systems Theory (EST): At this stage, the participants were asked to express the factors or systems that best describe their thoughts and experiences on the subject and to identify the appropriate ones from the following items.

- **Individual/intrapersonal factors:** The person's feelings, thoughts, behaviors, attitudes, gender, education level, etc.
- **Microsystem factors:** Family, school, peers, physical environment, religious/spiritual resources
- **Exosystem factors:** Media, neighbors, social services, local governments, local organizations
- **Macrosystem factors:** Government policies, community values, economy
- **All of them**

Analysis of the Data: Online Interpretative Phenomenological Analysis (OIPA)

In this study, the data were analyzed based on the summary word groups obtained from the participants in the fourth step of the OPV. As it is explained above, the participants provided the summary words based on their stories and photographs. The themes that emerged as a result of the analysis in this current study were not determined by the researcher as in the traditional IPA. The themes were shaped from the participants' own summary word groups as suggested in OIPA by Tanhan (2020). Thus, main

theme groups were formed in line with the themes determined by the participants. This situation prevented the participants' views from being affected by any other factors and ensured that the themes were formed directly in line with the views of the participants. The researcher, on the other hand, ensured the formation of main themes by combining the summary word groups or themes put forward by the pre-service teachers as suggested in the OIPA (Tanhan, 2020; Tanhan & Strack, 2020). Thus, the analysis was ensured to be objective as some other researchers had used OIPA in mathematics (Koç Koca, 2023).

In the study, the data obtained by following the OPV and the SHOWED questions were analyzed with the OIPA. Thus, findings on the areas that pre-service teachers associate TPACK with and their use of information technologies were obtained. The pre-service teachers' use of information technologies was determined with the help of the questions in the first part of the study. The areas that pre-service teachers associate TPACK with were thematized with the help of summary word in the fourth step of the OPV. At this 4th step of OPV, the themes shared by the pre-service teachers were combined by the researcher to form the main and final themes in the current study based on the researchers developed OIPA (Tanhan, 2020; Tanhan & Strack, 2020).

At this stage, the data set was analyzed jointly by the researcher and a mathematics education specialist in order to make in-depth meaning, interpretation and grouping of the emerging themes. This also increased the validity and reliability of the study. Thus, the main themes were formed from the summary word groups or themes (*see the section 2 2: Step 4: Summary Words in this current paper*) that the participants had shared by taking into account their stories they had created. When it was not clear to the data analysts which main theme to place the summary word groups or themes created by the participants, the stories and photographs written by the participants were consulted. Each participant's summary word group was placed under at least one and at most four main theme groupings. Finally, when it was determined that the number of people in the main theme groupings formed in the analysis was not expressed by 3% or more of the total number of the participants, then that main theme was included in the closest main theme. Thus, the data analyzers performed main theme groupings three times. The steps of analysis provided a holistic approach to the evaluation of the situations that emerged.

Findings

In the study, the areas that pre-service teachers associate TPACK with and their use of information technologies were examined with the help of the students' own statements and photographs. In the first stage of the data collection process, the demographic characteristics of the participants and their use of information technologies were investigated. Considering the demographic characteristics, it was determined that 50 of the 98 participants in the study were in the 2nd grade of the Elementary Mathematics Teacher Education Program and 48 of them were in the 3rd grade. In terms of age, the participants were between 20-25 ages and in terms of sex 68 of the participants were female and 30 were male. For income level, 24 of the participants stated that they had no income, 32 stated that their income was at a low level and 42 stated that their income was at a medium level.

Findings on Participants' Interest in Information Technologies

When the participants' use of information technologies was analyzed, it was seen that the participants expressed their level of computer use in four groups as “beginner, intermediate, good and advanced.” Accordingly, 22 of the participants stated that they could use computers at the beginner level, 56 at the intermediate level, 18 at the good level and two at the advanced level. Most of the participants were able to use computers at the “intermediate level”. Six students as the participants who stated that they can use computers at advanced (two students) and intermediate level (four students) stated that they had received training from experts or a course on information technologies before. The remaining 92 students stated that they did not receive any training.

Participants were asked to evaluate their average daily technology usage time. The participants stated that their daily technology usage time varied between half an hour and six hours or more. Accordingly, 48 participants reported that they used technology for two hours daily at most. 20 participants stated that they were together with technology for one hour daily, 14 participants for five to six hours daily, eight participants for three to four hours daily, four participants for half an hour daily and four participants for more than six hours daily. In addition, in terms of these usage categorization, it was determined that there were no participants who did not use technology at all during the day.

Without depending on existing knowledge, the participants’ frequency of the participants' use of Web 2.0 Applications such as Blog, Wiki, Podcast, Social Networking, Learning Management Systems or Instant Messaging that support their individual learning was examined. Thus, the participants' ability to create, interpret and use online content in the field of education without installing programs on their computers was evaluated. Since the participants could express more than one opinion in this step, a total of 238 opinions emerged. In the analysis, it was seen that the participants mostly used social networking (82 opinions). Participants gave 57 opinions for instant messaging, 39 opinions for learning management systems, 27 opinions for blog, 21 opinions for podcast and 12 opinions for wiki.

Findings on the areas that the participants associate TPACK with Table 1.

In the second stage of the data collection process, the TPACK-related domains of pre-service mathematics teachers were examined. The TPACK-related domains of the participants were determined with the help of the steps in the second part of the OPV form. The TPACK-related domains of the participants were thematized with the help of the keywords determined by the participants themselves in the 4th step of the 2nd section of the form. As a result of the analysis of the data obtained, 37 themes emerged. Among these themes, those that were not expressed by 3% or more of the total number of participants were included in the closest theme group by interpretation. For example, the “dangerous” theme that emerged in the first analysis was combined with the “harmful” theme in the second analysis. Thus, the number of themes decreased to 31. The themes that were not expressed by 3% or more of the total number of participants in the second analysis were analyzed again and included in the closest theme group. While doing this, the photographs and stories created by the participants themselves were taken into consideration. Thus, as a result

of the third analysis, the total number of themes was reduced to 17 and the analysis was finalized. The themes obtained are presented in Table 1.

Table 1. Main Themes Related to the areas they associate TPACK with

	Main Themes	Participants (Total 98 particpants)	%
1	Life	K3, 9, 10, 11, 12, 14, 16, 19, 24, 27, 29, 31, 39, 41, 47, 48, 50, 51, 53, 54, 55, 58, 61, 67, 68, 69, 70, 72, 75, 83, 86, 87, 90, 93, 94, 96	36
2	Increase of knowledge	K16, 32, 36, 41, 43, 46, 47, 49, 51, 53, 57, 60, 61, 64, 65, 67, 68, 69, 71, 73, 76, 77, 82, 84, 87, 88, 94, 97, 98	30
3	Concretization	K4, 7, 15, 26, 44, 47, 49, 52, 57, 59, 63, 66, 68, 70, 72, 76, 79, 80, 81, 83, 84, 87, 96	23
4	Learning	K10, 30, 42, 43, 56, 59, 63, 67, 72, 75, 81, 82, 25, 73, 90, 95, 97	17
5	Education	K1, 15, 18, 31, 38, 40, 42, 51, 60, 64, 66, 71, 83, 84, 89, 94	16
6	Using consciously	K2, 5, 6, 34, 37, 44, 45, 59, 71, 78, 79, 81, 95	13
7	Internet	K19, 23, 46, 48, 54, 62, 65, 77, 80, 85, 91, 93, 98	13
8	Relating technology to mathematics	K20, 21, 23, 31, 35, 39, 45, 46, 62, 65, 80, 91, 96	13
9	Emerging curiosity	K28, 33, 49, 55, 58, 77, 86, 90, 93, 97, 98	11
10	Artificial intelligence	K23, 32, 43, 54, 55, 66, 70, 85, 92, 93, 97	11
11	Contribution to education	K8, 31, 43, 44, 50, 52, 56, 60, 74, 88	10
12	Programs used in teaching mathematics	K10, 11, 13, 16, 73, 74, 79, 88, 89	9
13	Developing imagination	K26, 58, 63, 69, 82, 86, 92	7
14	Communication	K5, 32, 50, 64, 73, 74, 95	7
15	Saving time	K36, 49, 76, 89, 98	5
16	Importance	K22, 48, 56, 85, 92	5
17	Harmful	K3, 78, 17	3

*Participant percentages are rounded to the nearest whole number.

When one check Table 1, it is seen that the areas that pre-service mathematics teachers associate with TPACK consist of 17 themes. When the themes are examined, it is understood that some participants expressed opinions on more than one theme. Providing more than one theme contributed to the in-depth examination of the participants' views on TPACK. Participants addressed TPACK with themes that explained TPACK in a positive way such as knowledge increase, concretization, learning, and life. The only theme with a negative view is the theme that TPACK is harmful and theme consists of a total of three participants. Accordingly, it is seen that the participants associated TPACK with the theme of life (36%) at the most and with the theme of harmful (3%) at the

least. The stories and photographs that attracted attention in the study were analyzed with the help of themes.

The theme in which TPACK is associated with life is the theme in which the participants expressed the highest number of opinions (36%). When the explanations of the participants related to this theme are examined, it is seen that it is mostly discussed due to the fact that technology has become integrated with life and is frequently used in every field.

> *The development of technology has also contributed to the field of pedagogy. Nowadays, we can use the features of each concept and transfer it to the computer environment. In this way, we have more access to the lives of students and people." (Participant 87th), 'With appropriate tools, subjects and transfers, it has become used in all of our lives, everyone now has various tools to access the internet.' (P41), "In my own educational life, I never had the opportunity to access pedagogical areas with computers. But now it has become life itself." (P12).*

None of the participants who associated TPACK with the theme of "life" associated TPACK with the theme of using TPACK consciously but most of them associated TPACK with knowledge increase. Below is a photograph in which P16 combined the themes of life and knowledge increase with the theme of programs used in mathematics teaching.

Photograph 1. Photograph and Story Submitted by P16

P16 shared their story by combining the themes of knowledge increase, life and programs used in mathematics teaching.

> *At the moment, we can say that human beings are quite advanced in every field. The computers and the internet that we use in in our daily life in recent years are clear evidence of this. Of course, I believe that we reached our current situation with the conscious use of the increase in knowledge over time. The same is true for mathematics. We are now intertwined with technology in every aspect of our lives. (P16)*

> *When we look at the internet theme, it is seen that the participants associate TPACK with easy access to increasing information. "The accumulation of knowledge is constantly increasing day by day. TPACK is also increasing. We should keep up to date and adapt to it. The easiest way to do this is to benefit from the constantly updated internet environment." (P65).*

Another striking situation is that the theme of "knowledge increase" is frequently associated with the theme of "time saving" to explain the effect of the theme of knowledge increase on TPACK. The participants explained this situation as *"...preventing the loss of information and time and ensuring safe information transfer through correct educational practices"* (P98). P79 stated that safe educational practices provide comfort in reinforcing and transferring information and also help to concretize abstract concepts or situations that are difficult to understand (Photograph 2).

Photograph 2. Photograph and Story Submitted by P79

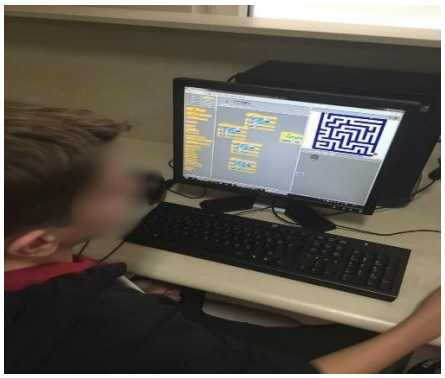
> *Although it shows a lecture in a different discipline, I think TPACK overlaps with this photograph. Here, there is the correct use of the smart board in a lesson and its integration into the lesson. Each lesson can have its own complex topics. If we use such applications in the lessons, we can help students to concretize complex concepts. This will directly affect the learning of the lesson (P79).*

Other participants explained the theme of concretization as *"Understanding difficult and complex subjects can become easier when combined with technology."* (P26), *"When we combine subjects with technology and use it well, we can turn it into an advantage in teaching."* (P83).

The theme of concretization can be connected with the theme of associating technology with mathematics, but only P80 and P96 did this. In their explanations,

> *"Mathematics may require us to think about the shapes of objects of different sizes etc. due to its nature. This is one of the areas where students have the most difficulty. In fact, when we concretize such subjects with the help of technology, we make them easier to understand." (P96), "Today, the internet has enabled information to be shared with many people. Of course, the programs in which we associate technology with course subjects also make an important contribution to concretization. For this reason, a teacher should know and use TPACK well."* (P80).

P56, who states that students' success in mathematics is related to a lot of repetition and practice, explains this in Photograph 3 as follows. *"Children need a lot of practice to learn the subjects better. In this photograph, I observe a technological game that will make the exercises fun. I think this is important. Thus, an important contribution will be made in mathematics education."* From these explanations, it is seen that the participant associates TPACK with the themes of Learning, Importance and Contribution to Education.



Photograph 3. Photograph Submitted by P56

"In recent years, the number of educational practices developed for reinforcement has increased considerably. When I do my job, I will definitely do these with my students. Because I believe that children should love mathematics. For this, we should leave the old methods. We should contribute to learning by using technology." (P10). When the participant's explanation is examined, it is seen that the theme of learning is emphasized. The theme of learning is ranked 3rd in this current studt. This shows that it is considered important by the participants (17%). *"I think it is effective in providing permanent learning." (P42), "TPACK has important contributions in education. Especially providing students with the opportunity to reinforce is effective in the realization of learning. Especially today, considering the development of artificial intelligence and its contributions to teaching, it can be said that TPACK has become more important." (P43).*

Artificial intelligence has become used in many fields today. Undoubtedly, it is effective in developing applications that are also used in the field of education. Some of the participants evaluated this situation of artificial intelligence in education. *"It has become closely related to human life, which shows that it has gotten its place in education. While making connections, we need to be individuals who are curious and look to the future with hope. As educators, we should devote more time to technology, pedagogy and artificial intelligence and we should be able to apply it." (P55), "Since I have a better visual memory, I remember what I see more and learn quickly. For this reason, I think artificial intelligence contributes to education and TPACK because it increases concretization and visualization. " (P66).* On the other hand, P93 and P97 stated that the themes of artificial intelligence and cultivating curiosity support each other. *"Curiosity is an important step for development. Of course, artificial intelligence cultivates curiosity in us with what it can do. We should turn this situation into an advantage and transfer it to education with TPACK." (P93), "The point artificial intelligence has reached is tremendous. It is incredibly interesting. It should definitely be used in teaching mathematics to children by making them love mathematics." (P97).*

The advancement of technology and its transfer to the field of education has enabled the increase of online applications in education. Evaluating this situation, P64 states that the development of Communication and Education has brought along the increase in Knowledge. He explains this situation in Photograph 4 as follows.

When we look at the photograph, we see people working together. I think that the use of technology contributes significantly to people here in terms of communication. It makes it easier to convey what is wanted to be conveyed. We can think of a similar situation for education. The fact that it enables collaborative learning shows the importance of TPACK in education in terms of ensuring communication and increasing knowledge. (K64)

Photograph 4. Photograph Submitted by P64

Finally, when we look at the Harmful theme, which differs from the other themes in terms of perspective, it is seen that the participants mentioned the negativities that technology can cause in human life. P17 explains this situation in the photograph he shared (Photograph 5) as follows.

Photograph 5. Photograph Submitted by P17

In the middle school period, children do not engage in any creative thinking or kinesthetic movement and experience their emotions virtually on a phone or tablet screen, which leads to a lack of progress in both brain and physical development. There is even regression. In the photo, I wanted to show that a girl with a toy prefers a phone and won't put it down. The problem is that children always have access to the internet and can easily access any website. I think until a certain age children should only have access to educational websites. TPACK becomes important here too. Because it should be prepared according to the level of the child. Children should be in real life environments rather than virtual environments. (P17).

When we look at the explanations of P17, it is seen that he mentioned the possible negative effects of technology on children instead of TPACK. In terms of TPACK, it is seen that the participant expressed an opinion that the information to be conveyed to children in the sentences he emphasized about education should be filtered and presented in terms of domain

knowledge. When Table 1 is examined, it is seen that P3 also expressed a negative opinion on this issue. "I see young children using technology. I wonder if they are using it in a beneficial or harmful way. Does it contribute to their development? As educators, we should address these issues. We should give children controlled educational environments that they can benefit from by developing our TPACK skills. We should make parents aware of this issue." (P3).

The last item of the OPV form provides a general evaluation of the systems to which pre-service mathematics teachers attribute TPACK . At this stage, pre-service teachers were given explanations of individual, microsystem, exosystem and macrosystem domains. The participants were asked to determine which one or which of these domains affected TPACK the most. The findings obtained from the participants are as follows (Table 2).

Table 2. "TPACK" Attribution to Systems

Attributed Systems	Individual	Microsystem	Exosystem	Macrosystem	All Together
Number of the participants and percentages	41 (20%)	52 (25%)	35 (17%)	30 (14%)	50 (24%)

*Person percentages are rounded to the nearest whole number.

When Table 2 is examined, it is seen that pre-service mathematics teachers associate TPACK with Microsystem elements the most. Microsystem elements include situations such as family, school, peers or physical environmental conditions. In other words, microsystem elements refer to activities, roles or interpersonal relationships in certain environments where face-to-face communication is realized. Therefore, they contain the elements of the closest relationships that affect the development of the individual most rapidly and directly. From Table 2, it is seen that the participants proceeded systematically when referring to systems other than individual elements. In other words, according to the participants, when the environment they interact with expands, its effect on TPACK gradually decreases. Accordingly, it can be said that the participants think that microsystem elements and individual development have important effects on TPACK.

Discussion, Conclusion and Recommendations

In this study, pre-service mathematics teachers' use of information technologies and their ability to transfer it to educational environments with the help of technological pedagogical content knowledge were examined. Both situations were analyzed with the help of OPV. Thus, it was determined that the participants were able to use computers at a moderate level and very few of them were able to receive expert support. From a professional point of view, this situation is remarkable. Because in recent years, it is stated that the competencies of teachers and pre-service teachers in the use of computers, information technologies and the internet have continuously increased (Bayyiğit Teker, 2019; Kırmızıgül, 2020). This situation is not similar to the research findings. This result may have been caused by the fact that instructors do not use or do not want to use Web 2.0 applications in undergraduate courses (Korucu &

Karalar, 2017) or the deficiencies in the use of visual and auditory resources due to the prevalence of traditional education models (Kara, 2011). In addition, it was determined that the participants were engaged in technology-related activities during the day. Participants stated that they use social networking sites the most among Web 2.0 applications. However, studies show that today's teaching profession is integrated with technology and is positively affected by technology in terms of fast access to information and effective use of internet and social networks (Günüç, Odabaşı, & Kuzu, 2013). This situation reveals that the information and technology literacy of pre-service teachers should be addressed and improved.

When the areas that the participants associated TPACK with were examined, it was determined that they mostly expressed TPACK with main themes such as life, knowledge increase, concretization, and education. The fact that internet and information technologies are frequently used in every aspect of our lives in today's conditions shows that pre-service mathematics teachers are also affected by these daily experiences. This situation allows the existing knowledge to increase quite rapidly and spread to large populations. Especially the fact that they addressed this under the theme of life is a clear indication of the impact of these experiences on the participants. The continuous renewal, change, development and diffusion of information technologies enable information technologies to have a great impact on areas such as social transformations, media and education (Akgün, 2020). Similar to the literature, this situation stands out clearly in the current study. It would not be wrong to say that this situation also makes great contributions to education. In particular, the fact that it allows people to conduct research and obtain existing information quickly and uninterruptedly contributes greatly to their self-development. In this respect, in the trainings given to the participants on information technologies, it should be avoided to give trainings only on how to use technological tools. Instead, training should be planned by taking into account the technological, pedagogical and mathematics content knowledge needs of prospective mathematics teachers. In this way, teachers can contribute to creating environments where they can include their students in the process.

On the other hand, the fact that mathematics course includes abstract skills due to its structure makes the materials used in education important. In this respect, it is important that the participants stated that they can be used to concretize abstract subjects in terms of TPACK. The integration of multiple learning environments into mathematics education supports students to concretize abstract concepts by involving different sensory organs (Bacon & Bounty, 2020). In addition, studies show that animations allow learners to actively participate in the learning process and abstract concepts that are difficult to understand can be easily structured in the mind (Barrocas et al., 2023). In this respect, it is important for the participants to be aware that TPACK supports learners' concretization skills (conscious use) and to be able to include it in the educational process. This situation also supports the participants to use various technological tools that they can include their students in the learning process and programs and software that they can use in mathematics teaching. As a matter of fact, it is seen that the pre-service teachers expressed this situation under the main themes of programs used in mathematics teaching and associating technology with mathematics.

Considering all these, it is revealed that the participants use TPACK in an integrated way in education engaged with life.

TPACK has many benefits for teachers. Saving time in education, facilitating learning, enriching teaching and providing permanent learning are some of them. In the current study, it was determined that the participants associated TPACK with themes such as enriching communication, saving time, enriching teaching with the help of the internet and having a very important place in today's conditions. Integration of technological tools and contents with pedagogy contributes greatly to go beyond traditional education studies in mathematics education (Viberg, Grönlund, & Andersson, 2023) and to make learning permanent (Namlu, 1999). In this respect, it is seen that the views of the participants overlap with the literature. Students should be provided and supported with environments that develop their conceptual and procedural skills in mathematics education with the help of technology and technological tools. For this reason, it is thought that it would be useful to integrate teaching styles with today's conditions in teacher training programs. It should be ensured that teachers prefer to use technology as a tool in teaching. For this, pre-service teachers need to be motivated, trained and equipped with the necessary skills (Keengwe, 2007).

It was observed that very few of the participants expressed negative opinions about TPACK and the use of technology in education. The participants who expressed negative opinions cited the inability of children to develop nature-integrated skills and loneliness because they were exposed to technology too much. In the literature, it is seen that the relationship between technology and loneliness is frequently addressed on a dialectical plane (Grudin & Jacques, 2019). It can even be said that artificial intelligence-supported chat applications were developed by being influenced by this gap. Interpersonal communication is a need that allows people to meet their basic needs through mental and physical ties with their environment (Farina et al., 1991). Some of the studies in the literature indicate that technology has a negative impact on social life and interpersonal communication practices and increases loneliness (Sullivan et al., 2023; Shao et al., 2022; Zamora, 2017). Therefore, the views of the participants are integrated with the literature. Pre-service teachers should be informed about the situations in which technology and TPACK can be negatively affected and the measures that can be taken should be expressed. Thus, mathematical language and experience can be meticulously planned (Koç Koca, 2023) and negative situations can be prevented.

In the study, it was seen that the participants associated TPACK with Microsystem elements the most. Participants think that individual development is also very important in this process. The data obtained show that the effect of this association decreases as the system expands. It can be said that the participants think that microsystem elements and individual development have important effects on TPACK. Studies in the literature show that positive relationships established with the microsystem, which includes the immediate environment consisting of people with whom the individual interacts directly, have positive effects on the development and life of the individual (Eslek & Yılmaz Irmak, 2018).

It is seen that multidimensional education systems are formed due to the high interaction of technology in many areas of life and offer an effective education model when combined with face-to-face education. For this reason, the transfer of mathematical knowledge by using it effectively will enable the training of qualified individuals with the dynamic microsystem elements acting together. The effective use of knowledge in the microsystem can be developed by establishing a non-directional educational relationship correctly and integrating it with other variables. In this respect, it can be said that TPACK plays a very important integrative role in a system that is intertwined like matryoshka dolls. Considering the contributions of individual effects and environmental factors in these changes, a broad perspective should be presented in teacher training and the development of prospective teachers in this context should be ensured.

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