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An Analysis of the Relationship between Elementary Mathematics Teachers' Technological Pedagogical Content Knowledge (TPACK) Competencies and Their Use of Information and Communication Technologies (ICTs)*

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Abstract

This study aims to reveal the nature of the relationship between elementary school mathematics teachers' TPACK (Technological Pedagogical Content Knowledge) competencies and their use of ICTs.The convergent mixed method was used, and 185 elementary school mathematics teachers participated in the sampling of the quantitative phase of the study. 30 elementary school mathematics teachers voluntarily formed the study group of the qualitative phase. Technological pedagogical content knowledge competencies scale, information, and communication technologies (ICT) competence perception scale for preservice teachers, and semi-structured interview form were used as the data collection tools. The quantitative data obtained from the research were analyzed with arithmetic mean, standard deviation, frequency, percentage, t-test, one-way analysis of variance and Tukey test. The content analysis technique was used in the analysis of the qualitative data, the quantitative data were modeled by applying the SPSS program, and the qualitative data were modeled by using the N-Vivo program. The findings show that elementary school mathematics teachers feel self-competent in TPACK. Similarly, elementary school mathematics teachers were also found to feel efficacious in using their ICT skills. Elementary school mathematics teachers' perceptions of competency in TPACK were found to differ significantly by the variables of gender, computer education status, level of computer knowledge and daily use of the computer. In addition, was determined that elementary school mathematics teachers' efficacy perceptions for the use of ICTs differ significantly by the variables of gender, computer education status, level of computer knowledge, and daily use of the computer. It was further revealed that elementary school mathematics teachers mostly use the computer for tasks related to their lessons and for research purposes.

Keywords: Perception, Information and Communication technologies, Elementary mathematics, Mixed method, Technology, Technological Pedagogical Content Knowledge (TPACK).

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Introduction

Recognizing the importance of developing technology knowledge for teachers, teacher training programs have begun to design and teach curricula focused on preparing teachers to use technology in the classroom. To facilitate the integration process, Mishra and Koehler (2006) developed a conceptual framework called Technological Pedagogical Content Knowledge (TPACK), which emphasizes how technology knowledge, pedagogical knowledge, and content knowledge interact to develop discipline-specific technology learning experiences. Since the first development of TPACK, many researchers have further developed curriculum, texts and professional growth modules that complement the framework. (Archambault, 2016). Koehler and Mishra (2009) state that technology is one of the basic components of teaching, but they also express concerns about the fact that teachers do not have sufficient knowledge and opportunities to use technology in their classrooms. Although teacher education programs recognize the importance of technology integration, these same programs have struggled to find effective curriculum-level and instructional-level strategies that adequately prepare preservice teachers to integrate technology into their future classrooms (Göktaş, Yıldırım, & Yıldırım, 2008).

What is TPACK?

TPACK was introduced to the educational research field as a conceptual framework for understanding teacher knowledge required for technology integration (Mishra & Koehler, 2006). TPACK developed from Shulman's (1986) pedagogical content (PCK) theory and focused on the need for teachers to skillfully demonstrate their ability to incorporate technology into constructs in domain (content) and pedagogical domains. TPACK can be viewed as a teacher's intuitive understanding of teaching subject-specific content with appropriate pedagogical methods and selected technologies. Teaching is a complex cognitive activity that requires teachers to use various types of knowledge (Koehler & Mishra, 2009). While TPACK serves as a useful conceptual framework for thinking, analyzing and evaluating what teachers need to know to integrate technology into teaching, it should ultimately be understood as a framework for the ways in which teachers can best develop this integrated knowledge (Baran et al., 2011).

Theoretical foundations of the TPACK Framework include a) Shulman's Pedagogical Content (Content) Knowledge, b) Pierson's technological pedagogical content knowledge, c) Koehler and Mishra's TPACK. In his article titled *Knowledge and Teaching: Foundations of the New Reform*, Shulman (1986) stated that in teacher education, content area knowledge was always assumed to be sufficient for teachers to teach students successfully. However, he argued that knowledge of the content is insufficient for effective teaching. Rather, he advocated the need for teachers to have pedagogical knowledge, that is, knowledge of how to teach. Shulman pointed out that while pedagogy represents the domain of teachers, content is the domain of students. By accepting content knowledge and pedagogy as mutually exclusive areas, Shulman pioneered the development of teacher education programs focused on the subject or pedagogy (Mishra & Koehler, 2006). Pierson (2001) is one of the first researchers to officially introduce the concept of Technological Pedagogical Content Knowledge. Her framework added teachers' technology knowledge to Shulman's established PCK. According to Pierson, the technological knowledge component should include an understanding of the characteristics of unique types of technology that impact specific aspects of learning and teaching processes, as well as basic knowledge competence. A teacher who combines technology appropriately is able to use broad subject knowledge and pedagogical knowledge along with technological knowledge. According to Pierson, sitting at the intersection of these three types of knowledge, TPACK defines effective technology integration. Finally, Koehler and Mishra's TPACK emphasizes that TPACK is more than teachers' close relationship with the subject (content), pedagogy, and technology to gain knowledge on how technologies can help students learn content (Groth et al., 2009). In short, they emphasize that TPACK is a framework for conceptualizing teacher knowledge needed to teach appropriately with digital technologies (Voogt & McKenney, 2017).

TPACK Domain Definitions

a. *Content Knowledge (CK):* Content knowledge (CK) is a deep knowledge of the subject to be learned or taught and is critical for teachers. The content covered in a middle school science course is different from the content covered in an undergraduate arts course or graduate seminar on astrophysics. As Shulman (1986) states, this knowledge includes theories, ideas, organizational frameworks, evidence and event information, knowledge concepts, as well as established practices and approaches to developing such knowledge (Koehler & Mishra, 2009; Mishra & Koehler, 2006).

b. *Technological Knowledge (TK):* According to Mishra and Koehler (2006), technological knowledge (TK) is in constant flow and requires a deep fundamental understanding along with technology mastery. Because technology is constantly changing, it is difficult to define. Until recently, many of the technologies used in traditional classrooms, from textbooks to overhead projectors, were thought to be 'transparent' (Bruce & Hogan 1998, Mishra & Koehler 2006), or, in the words of Mishra and Koehler (2006), "they became mundane and they were not even accepted as technology".

c. *Pedagogical Knowledge (PK):* Pedagogical knowledge (PK) is teachers' deep knowledge of processes and practices or methods of teaching and learning. It covers general educational outcomes, values, and targets.

d. *Pedagogical Content Knowledge (PCK):* Mishra and Koehler (2006) emphasize that their ideas on pedagogical content knowledge (PCK) are consistent and similar to Shulman's idea of pedagogical knowledge applicable to teaching specific content. PCK is concerned with the representation and formulation of concepts, pedagogical techniques, knowledge of what makes learning of concepts difficult or easier, knowledge of what it brings to students' learning situation, and theories of epistemology. It also covers knowledge of instructional strategies that incorporate appropriate conceptual representations to address student difficulties and misunderstandings and foster meaningful understanding.

e. *Technological Content Knowledge (TCK):* Technological content knowledge (TCK) is teachers' knowledge of how technology and content are interconnected. Educators need to know not only the subject they teach, but also how the subject can be changed with the application of technology (Mishra & Koehler, 2006).

f. *Technological Pedagogical Knowledge (TPK):* Technological pedagogical knowledge (TPK) is the knowledge of the existence, components and capabilities of various technologies as they are used in teaching and learning environments, and knowing how teaching and learning can change when certain technologies are used in certain ways (Koehler & Mishra 2009, Mishra & Koehler, 2006).

g. *Technological Pedagogical Content Knowledge (TPACK):* Technological pedagogical content knowledge (TPACK) is an emerging form of knowledge that goes beyond the three components: content, pedagogy, and technology. Using technology is the foundation of good teaching and requires knowledge of how various technologies can be used to represent knowledge of concepts, what kind of pedagogical techniques can be used in constructive ways to teach content, what makes learning concepts difficult and easier, how technology helps students solve some of the problems they face, how students' prior knowledge can be used to build on current knowledge, develop new knowledge theories or strengthen old ones (Mishra & Koehler, 2006).

The use of ICTs in education and the integration of technology into education are also important, which are necessary and important for increasing the quality of education along with teacher competencies. Educational environments in Turkish educational institutions are equipped with the latest technology (Basic Education Project Phase I and Phase II, which took place between 1998 and 2003, FATIH project started in 2011). However, it is the teachers in Turkish educational institutions who are to use this technology.

The concept of "information technology" emerged at the end of the 1980s, with the use of data storage and data processing opportunities, which allow the use of computers in educational environments. With the emergence and use of online communication opportunities, this concept has transformed into the concept of "information and communication technologies (ICTs)" since 1992 (Pelgrum & Law, 2003). The concept of ICT first appeared in a report prepared by Dennis Stevenson for the UK government in 1997.

Today, we can talk about three functions of ICT in the education system: instructional, administrative, and sociocultural. Instructional practices started in the 1960s to increase effectiveness and efficiency in teaching processes, and they underwent a student-centered transformation in teaching strategies and methods in the mid-1980s. In the administrative sense, ICT has effects at three different levels: classroom, school, and education system. At the classroom level, ICTs are used for learning and teaching activities and student-teacher-parent interaction, at the school level, they are used for student and parent registration information system, and at the education system level, they are used for increasing administrative efficiency and ensuring reliable, fast and continuous information flow and communication with other schools and stakeholders, and regulation of school-environment relations. The heavy use of ICT resources in education positively changes the perspectives and competencies of stakeholders in this field regarding these technologies. As such, ICT resources have a direct and indirect cultural impact on the education field and society, which is one of the stakeholders in education (Hepp, Hinostroza, Laval, & Rehbein, 2004).

Examining the relevant literature reveals that studies on TPACK in the field of education are mainly conducted with pre-service teachers who continue their education in different subjects (elementary school mathematics, science, German, classroom) (Akarsu & Güven, 2014; İşigüzel, 2014; Karalar & Aslan Altan, 2016; Önal, 2016; Yiğit Koyunkaya, 2017). However, there have been some other studies focusing on science teachers (Bağdiken & Akgündüz, 2018), primary school teachers (Bozkurt & Cilavdaroğlu, 2011; Kumsal, Atakan et al., 2021; Sarı & Bostancıoğlu, 2018) and geography teachers (Doğru & Aydın, 2017; Doğru & Aydın, 2018) as well. Although there have been studies on mathematics teachers working at different education levels (Ardıç, 2021; Bal & Bedir, 2020; Bozkurt, 2022; Bozkurt & Demir, 2011; Temizsiz & Deniz, 2019; Karataş & Aslan Tutak, 2017), no research has so far focused on the relationship between elementary school mathematics teachers' TPACK and ICT in detail. Therefore, the current study is expected to fill this gap in the existing literature.

Aim of the Study

The main purpose of this study is to evaluate the relationship between elementary school mathematics teachers' TPACK competencies and their use of ICTs. In line with this purpose, the answers to the following questions are sought:

1. a. What is the status of elementary school mathematics teachers' TPACK competencies?

   b. What is the status of elementary school mathematics teachers' use of ICTs?

2. Is there a relationship between elementary school mathematics teachers' TPACK competencies and their use of ICTs?

3. What are the elementary school mathematics teachers' perspectives on their use of ICTs?

Method

Research Design

Convergent parallel mixed method, one of the mixed method types, was used in the research. The convergent parallel mixed method is a type that aims to collect various pieces of data related to the same subject to define the research problem clearly and comprehensibly (Morse, 1991). In other words, it is a method that aims to compare and complement the findings obtained from quantitative and qualitative research on a particular subject (Creswell & Plano Clark, 2007).

Population and Sample (Quantitative Phase)

The universe of the quantitative phase of the research consists of elementary school mathematics teachers working in primary schools in Çanakkale in the 2015-2016 academic year. Since the research was conducted directly on the universe, sampling was not used. The sample of the study consists of 185 elementary school mathematics teachers who were randomly determined. The personal information of the mathematics teachers participating in the research is given in Table 1.

Table1. Personal Information about Mathematics Teachers

Variable	Demographic Characteristic	(f)	%
Age	20-29	55	29,7
	30-39	91	49,2
	40-49	24	13,0
	50+	15	8,1
Computer knowledge level	Very good	13	7,0
	Good	67	36,2
	Moderate	93	50,3
	Low	12	6,5
Daily computer use	1-2 hrs	136	73,5
	3-4 hrs	49	26,5
	Total	**185**	**100**

When the teachers participating in the research were examined in terms of age variable, 55 (29.7%) of the teachers were in the 20-29 age range, 91 (49.2%) in the 30-39 age range, 24 in the 40-49 age range (13.0%), and 15 (8.1%) of them were aged 50 and over. In terms of the computer knowledge level variable, 13 (7.0%) of them had very good, knowledge of it, 67 (36.2%) had good knowledge, 93 (50.3%) had medium level knowledge, and 12 (6,5%) had low level of knowledge. In terms of the daily computer use, it was revealed that 136 (73.5%) of the teachers had 1-2 hours, and 49 (26.5%) of them uses the computer for 3-4 hours.

Study Group (Qualitative Phase)

The study group of the qualitative phase of the research consists of 30 elementary school mathematics teachers working in Çanakkale in the 2015-2016 academic year. Criterion sampling was used to select the sample. These criteria were determined as a) teachers' working in the field of elementary school mathematics, b) their voluntary participation in the research.

Data Collection Tools

The quantitative data collection tools of the research are the *Technological Pedagogical Content Knowledge Competencies Scale* developed by the researcher and the *Information and Communication Technologies (ICT) Sufficiency Perception Scale for Pre-service Teachers* developed by Şad and Nalçacı (2015). The qualitative data collection tool of the research is the *TPACK and ICT Interview Form*.

The Technological Pedagogical Content Knowledge Competencies Scale was developed by taking into account the scales used in the related research and the theoretical studies related to the literature. In addition, teacher opinions were taken into account in the development of the scale. The scale was developed by the researcher by testing its validity and reliability. The *Information and Communication Technologies (ICT) Sufficiency Perception Scale for Pre-service Teachers* was developed by Şad and Nalçacı (2015). It was used in the study by after its validity and reliability were tested by the researcher. The questions in the semi-structured teacher interview form were developed by the researcher, taking into account the theoretical studies in the literature and the items in the scales used in the research.

Data analysis

The quantitative data obtained from the research were analyzed with arithmetic mean, standard deviation, frequency, percentage, t-test, one-way analysis of variance, and Tukey test values. The content analysis technique was used in the analysis of the qualitative data of the research. The quantitative data were modeled with SPSS, and the qualitative data were modeled with the N-Vivo program. Since the research data showed parametric distribution, the analyses were conducted through independent sampling t-test, one-way ANOVA, Tukey test, and Pearson correlation analysis.

Table 2. Teachers' TPACK Scale Arithmetic Mean and Standard Deviation Results

Dimensions	$\overline{X}$	Ss
Technology and Content Knowledge	4,21	,74
Pedagogical Content Knowledge TPACK	4,49	,41
	3,99	,83
Technological Pedagogical Knowledge	3,15	1,08
Total	4,18	,56

As shown in Table 2, teachers' views on technology and content knowledge are as follows: "I totally agree" ($\overline{X}$ =4,21). In the dimension of pedagogy and content knowledge, teachers expressed their opinion with "I totally agree" ($\overline{X}$ =4,49). In the TPACK dimension, the teachers' opinion is "I agree" ($\overline{X}$ =3,99). In the last sub-dimension, the technological pedagogical knowledge, the teachers expressed their opinion with "I agree moderately" ($\overline{X}$ =3.15). Overall, the teachers' views on TPACK can be summarized as "I agree" ($\overline{X}$ =4,18).

Table 3. The Arithmetic Means and Standard Deviation Results of Teachers' Perception of Information and Communication Technologies (ICT) Competency

Scale	$\overline{X}$	Ss
Perception of ICT Competency	3,96	,68

Teachers' perceptions of ICT competency are "I agree" ($\overline{X}$ = 3,96). Thus, it can be said that teachers think that they have the competence to use ICTs. In other words, it can be said that teachers know the basic concepts and practices related to technology and can use the necessary technologies appropriately in the teaching process.

Table 4. Correlation between Teachers' Competencies in TPACK and Their Perceptions of ICT Competency

	TPACK	ICT
TPACK	1	,800**
ICT	,800**	1

p<.01

When Table 4 is examined, it is clear that there is a high level of positive and significant relationship between teachers' proficiency in TPACK and their perceptions of ICT competency (r=,800, p<.05). Accordingly, it can be said that as the TPACK competency levels of teachers increase, their perceptions of ICT competency also improve. Considering the coefficient of determination (r2=.64), it can be said that 64% of the total variance in TPACK competencies stems from ICT competency perceptions.

Opinions of Elementary Mathematics Teachers on Using ICTs in Lessons. In this part of the research, the views of elementary school mathematics teachers on the use of ICTs while planning, processing and evaluating their lessons were examined in the form of main and sub-themes, taking into account the qualitative data sources. The main theme was named "***Use of ICT***". The sub-themes created under the main theme were named as "***ICT use in the planning stage***", "***ICT use in the presentation stage***", "***ICT use in the evaluation stage"***.

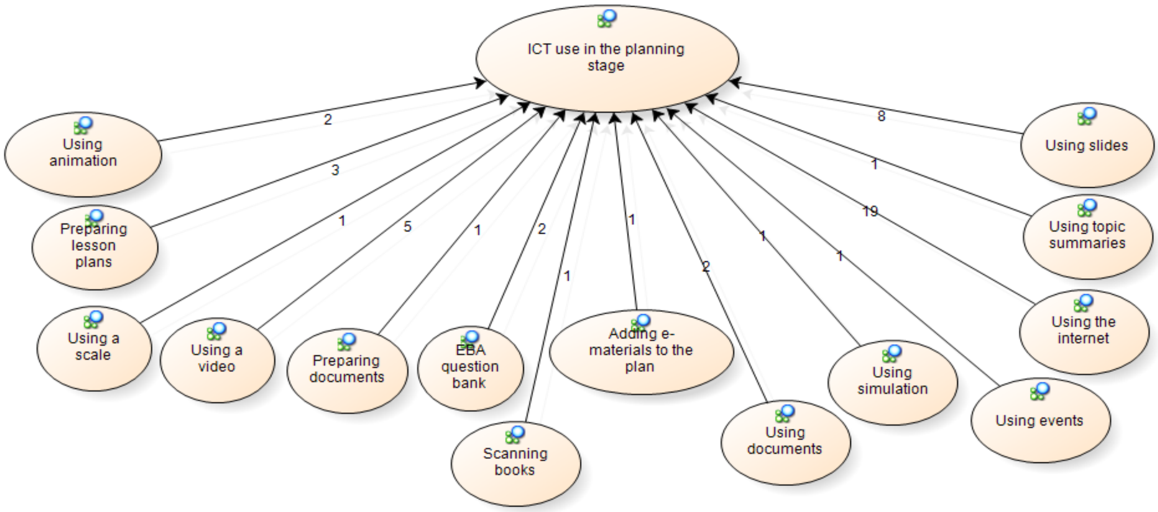

Figure 1. Using ICTs in the lessons in the planning phase

The sub-themes regarding the opinions of elementary school mathematics teachers about using ICTs in the planning stage in the lessons are: ***"Using animation", "Preparing lesson plans", "Using a scale", "Using a video", "Preparing documents", EBA question bank", "Scanning books", "Adding e-materials to the plan", "Using documents", " Using simulation", "Using events", "Using the internet", "Using topic summaries" and "Using slides".***

Teachers coded **T3, T5** and **T33** expressed their views on the subject as follows:

> *"While planning a lesson, I can use the internet and the documents to search for films, slides, animations, and simulations suitable for the lesson."* ***(T3)***
>
> *"I find the documents, worksheets, annual and daily plans required for the course on the internet and use them accordingly."* ***(T5)***
>
> *"During the planning phase, I try to prepare a broad plan by taking advantage of the resources like some internet sites, textbooks, reference books, EBA, etc."* ***(T33)***

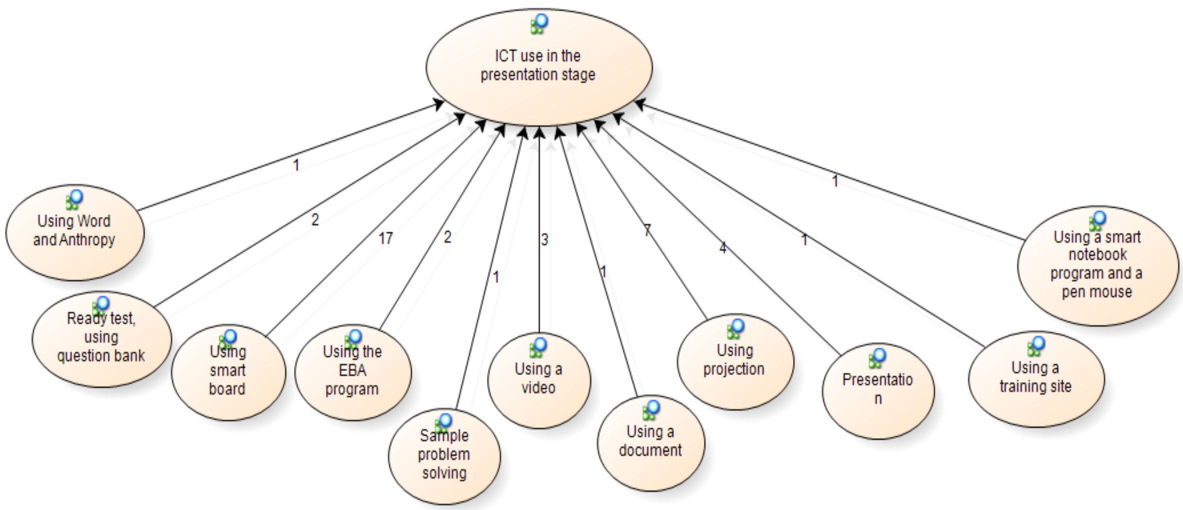

Figure 2. Using ICTs in the lessons during the presentation phase

The opinions of elementary school mathematics teachers about using ICTs in the lessons are grouped under the following sub-themes: ***"Using Word and Anthropy", "Ready test, using question bank", "Using smart board", "Using the EBA program", "Sample problem solving", "Using a video", "Using a document", "Using projection", "Presentation" "Using a training site", and "Using a smart notebook program and a pen mouse."***

T1, T10 and T37 expressed their views on the subject as follows:

> *"I actively use the smart board while teaching. It saves time, especially in solving questions."* ***(T1)***

> *"While I teach, I try to open a ready-made test or question bank and try to teach a lesson where children can actively compare their results."* ***(T10)***

> *"I teach by using the smart notebook program and PEN Mouse by scanning the books I will use before the lesson and reflecting them with a projection.* ***(T37)***

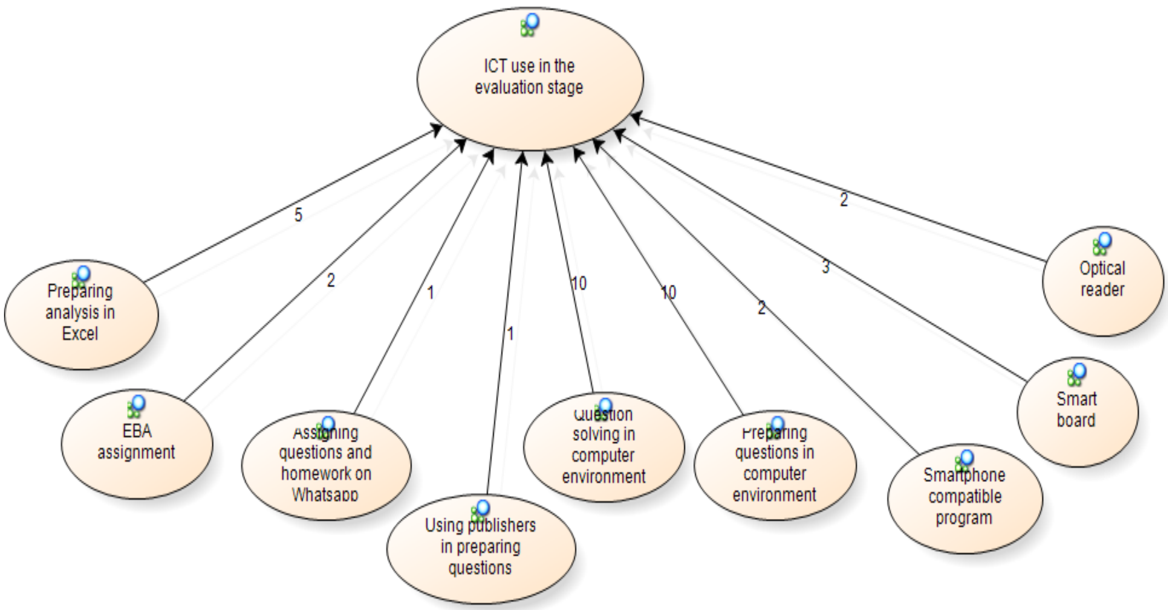

Figure 3. The use of ICTs in the lessons in the evaluation phase

The opinions of elementary school mathematics teachers on the use of ICTs in the lessons in the evaluation phase are are grouped under the sub-themes of ***"Preparing analysis in Excel", "EBA assignment", "Assigning questions and homework on Whatsapp", "Using publishers in preparing questions", "Question solving in computer environment", "Preparing questions in computer environment", "Smartphone compatible program", "Smart board", and "Optical reader".***

T18, T24, T26, T27 and **T33** expressed their views on the subject as follows:

> *"While evaluating, I search for exam questions, and I solve practice exam questions online with students in the classroom."* ***(T18)***

> *"When evaluating, I use the optical reader and the applications on the smartphones."* ***(T24)***

> *"The questions prepared while evaluating the lesson are solved on the smart board. I prepare analysis in excel about exam results. I give homework to students via whatsapp."* ***(T26)***

> *"I use it in preparing exams and preparing statistical results."* ***(T27)***

> *"In the evaluation, I examine the evaluations of the Ministry of National Education or*

*EBA and prepare the necessary evaluation. In the next stage, I use the Excel program.” **(T33)***

Conclusion and Discussion

Elementary school mathematics teachers' perceptions of self-competency in TPACK were revealed, who reported having sufficient TPACK. According to the quantitative data of the study, most of the mathematics teachers stated that they use digital technologies such as computers, internet and software programs in learning environments. In addition, teachers can use technology-supported scales in assessment and evaluation processes in lessons. Therefore, they can be said to create an effective learning environment by using technology, pedagogy, and content knowledge together.

In the study, elementary school mathematics teachers' perceptions of competency in ICTs were also examined, who reported that they viewed themselves sufficient in the use of ICTs. The qualitative data of the study support the quantitative findings data. The findings obtained from the interviews indicate that elementary school mathematics teachers apply ICT use in their lessons in the planning, presentation, and evaluation stages. Elementary school mathematics teachers use ICTs for the purpose of using the internet, preparing slides, and using videos while planning the lesson. Some of the elementary school mathematics teachers also use simulation and scale, add e-material to the plan, extract the subject summary, and scan the books. Elementary school mathematics teachers stated that they mainly benefited from ICTs for the purpose of using smart boards, projections, and presentations while presenting the course. In addition, they reported that they use Smart notebook program and pen mouse, word and anthropy and education site while presenting the lesson. Elementary school mathematics teachers were found to mainly use ICT for problem solving and preparing questions in computer environment and preparing analysis in Excel during assessment. At this stage, some teachers used WhatsApp to ask questions and assign homework, to use publisher to prepare questions, and to give homework from the EBA digital platform. It can be said that elementary school mathematics teachers use different technological tools in the planning, presentation, and evaluation stages. In addition, teachers take into account the principles of using different technologies during the planning phase. In the presentation phase, they use the tools for the course by taking into account the characteristics of different technological tools. In addition, at this stage, they use different technologies in the teaching process in accordance with the learning outcomes of the course. Considering the opinions of elementary school mathematics teachers about the evaluation phase, they are observed to use ICT when analyzing the outcomes (learning products). However, they also seem to evaluate the measurement results with alternative ICT-related assessment and evaluation tools (table, graph, etc.).

Another subject examined in the study is the correlation between elementary school mathematics teachers' TPACK competency perceptions and their ICT competency perceptions. A high level of positive correlation was found between elementary school mathematics teachers' competency in TPACK and their perception of ICT competency. Thus, it can be said that as elementary school mathematics teachers' competency perceptions towards TPACK increase, their competency perceptions towards ICT also increase. In other words, there is a linear relationship between these two variables. The increase in one of these variables affects the other variable positively. In other words, it can be said that elementary school mathematics teachers' perceptions of "Technology and Content Knowledge", "Pedagogy and Content Knowledge", "Technological Pedagogical Knowledge" and "Technological Pedagogical Content Knowledge" and "Information and Communication Technologies" perceptions affect each other positively. This finding is supported by the findings reported by Albayrak-Sarı et al. (2016). In addition, the findings of the research conducted with teacher candidates of different subjects also support this result (Balçın & Ergün, 2018; Şad, Açıkgül & Delican, 2015; Topçu, 2020; Yurdakul & Çoklar, 2014).

Suggestions

. It is necessary to organize learning environments that will improve the TPACK of elementary school mathematics teachers. Therefore, it can be suggested that the in-service trainings that will support elementary school mathematics teachers' online, in- and out- of- class teaching practices should be increased and supported by the Ministry of National Education.

The TPACK competencies and the interaction of technology-pedagogy, technology-content and pedagogy-content knowledge should also be taken into account in the technology-focused in-service trainings to be given to teachers. In these trainings, teachers should be shown how to teach using technology rather than how to use technology, in a hands-on manner.

To use ICTs more effectively and increase efficiency in schools, IT counselors should be appointed. In addition to this, IT guidance teachers should give practical training to teachers, administrators, and student groups at school at regular intervals.

It should also be ensured that in-service trainings on instructional technology application for elementary school mathematics teachers are given by people who are experts in the fields of both mathematics and technology.

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