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*Article*

# An Investigation of Turkish Pre-Service Teachers' Technological, Pedagogical and Content Knowledge

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**Abstract:** The purpose of this study is to investigate pre-service teachers' technological, pedagogical and content knowledge (TPACK) in Turkey. By using the "Survey of Pre-service Teachers' Knowledge of Teaching and Technology" developed by Schmidt *et al.* (2009), the study sought to determine if significant differences could be found in pre-service teachers' perceptions of TPACK when examined by gender, age, educational program, year of study, kind of instruction (day or night education) and field experience. Regression analysis was also used to examine if technology knowledge (TK), pedagogical knowledge (PK) and content knowledge (CK) significantly contributed to pre-service teachers' TPACK development. Participants of this study were 491 elementary pre-service teachers who attended the summer semester at Pamukkale University. The analysis of the collected data found a significant difference in pre-service teachers' perceptions of the TPACK when examined across gender, program, year of study and field experience, but no significant differences were found regarding age and kind of instruction. Finally, our regression model showed that CK and PK contributed significantly to pre-service teachers' TPACK development, but TK was not a significant predictor.

**Keywords:** TPACK; technology education; pre-service teachers' perceptions

## 1. Introduction

As a result of the developments in technology to improve the quality of life, technology has become ubiquitous in every aspect of living. Beginning with strong debates, being an issue in education, technology has turned out to be a trend, and it is here to stay. Education systems are no longer debating whether to integrate technology with schools; rather, they now consider how to use technology to enhance teaching and learning effectively. Teachers must improve their technology skills and pedagogical knowledge in order to provide opportunities for their students to improve their knowledge and skills, such as higher order thinking, creativity, communication and collaboration. Therefore, it became important to empower pre-service teachers, who will carry out new implementations, to use technology and to integrate it in their pedagogical instruction.

The world has long become digital with the computer age, and in this virtual world, there are digital natives and digital immigrants. It has been assumed that the new people coming into the teaching profession will be into technology, because they have grown up in the age of the personal computer and now the smartphone; however, older teachers are considered as digital immigrants [1]. Since pre-service teachers are considered as digital natives, it was expected that they would also use technology in their instruction naturally in the classrooms. However, some research showed that although the availability of hardware, software and Internet connections continues to increase in schools and colleges, many beginning teachers and pre-service teachers do not have the necessary knowledge or experience to integrate the technology into their instruction [2–8]. In this regard, it is found that knowing how to use technology and using it for individual purposes all the time does not mean that teachers can integrate technology efficiently into their instruction to improve teaching and learning. Hence, although technology knowledge is important, it is not an indicator of making use of technology in instruction to enhance teaching and learning. Therefore, technology, pedagogy and content knowledge should be considered all together in teacher education programs.

It is imperative that teacher education programs train pre-service teachers to use computers and related educational technologies, so that prospective teachers understand the possibilities that educational technology offers for curriculum expansion and enhancement. Technology education must go hand in hand with pedagogy and be relevant to other teaching functions. Once they are given sufficient technology education during their degrees, pre-service teachers might easily figure out how to integrate technology into their future instruction [9]. The U.S. Department of Education stated in the last National Education Technology Plan [10] that technology's promise to improve learning needs to be leveraged. It is stressed that the most important factor in a student's success is the teacher leading the class, and technology in the classroom only works when paired with effective teaching. Consequently, technology training for teachers to integrate technology into instruction remains profoundly emphasized.

Besides sufficient technology education, some research revealed that value beliefs are the best predictor of pre-service teachers' intentions to use a variety of software and their intentions regarding frequency of technology use with students in their future classrooms [11,12]. Technology knowledge is unlikely to be used unless teachers can conceive of technology uses that are consistent with their existing pedagogical beliefs [13]. Perceptions of the importance or relevancy of a task for the accomplishment of future goals significantly influenced pre-service teachers' intentions of technology use [11]. It became clear that simply increasing computer access was not sufficient to change teachers' technology practices, especially if this increased access was not accompanied by a corresponding shift in teachers' pedagogical beliefs [8,14]. Consequently, exploring pre-service teachers' perceptions may help us to understand if they tend to integrate technology into their instruction when they become teachers.

In this paper, the technological, pedagogical and content knowledge (TPACK) framework [15] was used to examine the pre-service teachers' perceptions of TPACK. Additionally, a model was also derived using multiple-regression to describe variables that significantly contributed to pre-service teachers' TPACK development.

### *1.1. Technology Use in Teaching*

In the 21st century, effectively-used technology can help all students meet and exceed rigorous learning goals by providing access to tools and resources that personalize instruction and creating rich, engaging and relevant learning environments [16]. As technology integration continues to increase, it is paramount that teachers possess the skills and behaviors of digital-age professionals. Moving forward, teachers must become comfortable being co-learners with their students and colleagues around the world [17].

According to the U.S. National Center for Education Statistics [18], teachers sometimes or often used word processing software, spreadsheets and graphing programs, software for managing student records, software for making presentations and the Internet for instructional or administrative purposes. Moreover, the reported results in the literature about teachers' technology use are wide and varied. While Fisher, Denning, Higgins and Loveless [19] stated that to support learning, teachers use technology for distributed thinking and knowing, engagement and motivation, communication and knowledge building, other studies reported that teachers use technology to give students practice on content and skills, use examples that are familiar to students when explaining things, use the Internet to find activities or content for class, create learning materials for students on the computer or assess student learning on instructional objectives [20,21]. Furthermore, Bang and Luft [22] concluded that teachers used PowerPoints for teacher-centered lecture-style classes, whole-class setting arrangements or reviewing facts for exams; they used websites mostly for one-way communication during their science teaching by either showing video clips or pictures found on relevant sites to help students understand the scientific facts they learned; on the other hand, they did not use websites nearly as often for generating class discussions promoting collaborative learning or creating knowledge. Therefore, it is emphasized by some researchers that a majority of teachers use technology to support low-level curricular task for assisting traditional teaching and learning, not necessarily for high-level tasks to engage learners as active contributors to the learning process [22,23].

In Turkey, aligning with the studies mentioned above, it is revealed that teachers' use of technology is limited to supporting their traditional ways of teaching and administrative purposes [21,24,25]. Overall, teachers are mostly using the Internet and word processing software to prepare the documents for instruction, homework and assessments and using PowerPoint presentations to deliver the contents of the subject matter [6,21,26–29].

*1.2. Technology Education*

New technologies have changed the nature of the classroom or have the potential to do so because technology has the power to change the ways of representing and formulating subjects to make them more accessible and comprehensible [15]. In a sense, technology has fundamentally altered how we live and work, as well as how we learn. Not only has the nature of classroom learning been changed, but also the very concept of the classroom itself has been redefined by the proliferation of distance education and e-learning [30].

As the role of technology has evolved from the role of assisting the teacher in personal management to using technology for instruction, universities are altering courses to infuse the introduction and utilization of technological tools to enhance instruction [31]. Technology education is moving from a stand-alone technology course to technology-integrated curricula and context-specific approaches, modeling of technology use by college educators, faculty development and providing opportunities to prospective teachers to use technology [4]. Increasingly, teachers are being prepared to teach in innovative ways, such as: blended classrooms that include virtual, as well as face-to-face learning; classrooms where students use digital devices as personal learning and productivity tools; using digital content and Web 2.0 tools; and using data to guide and assess their students' learning [32].

However, despite increases in computer access and technology training, as mentioned, technology is under-used by prospective teachers and beginning teachers to support the various kinds of instruction [3]. As a reason, researchers indicated that although pre-service teachers may know the basic functions of technology use in the classroom, they might be unprepared to truly integrate these skills into their teaching; therefore, teacher preparation programs may not be doing enough to prepare pre-service teachers to effectively use technology [33].

In many early models of implementing technology into teacher education programs, prospective teachers took a computer literacy class separate from content methods classes and rarely engaged in real collaboration on how teachers could integrate technology into authentic learning experiences; thus, by focusing merely on how to use computers, technology training failed by not addressing how to teach students more effectively using a variety of technological tools [34]. Therefore, naturally, there was a disconnect between technology training and the rest of teacher preparation program. As a result, research indicated that pre-service teachers believe that isolating the technology training in a single course did not allow them to retain and transfer to their classroom teaching the information gained from this course [35]. Moreover, pre-service teachers stated that the concentration of all of their technology training into a single course made the learning process too intense, even overwhelming.

This issue is not any different for technology education for pre-service teachers in Turkey. Although using computers in education began in 1984, then computer-aided instruction was included in 1991 [36], pre-service teacher curricula did not require teacher candidates to take any technology-related course to fulfill the requirements for their teaching until 1998 [29]. "Computer" and "instructional technology and material development (ITMD)" courses became mandatory in teacher education programs in 1998 [37]. A "computer" course was to provide basic concepts and computer applications, such as word processors, presentation software, the Internet, *etc.*, and an "ITMD" course was designed to provide knowledge and skills about the function of instructional technology in learning process and selecting appropriate technologies to enhance teaching and learning [37]. The results of Goktas, Z. Yildirim and S. Yildirim's [37] research about pre-service teachers' opinions about the effectiveness of technology-related courses revealed that although pre-service teachers were positive about the effectiveness of technology-related courses, they think that these courses were relying more on theoretical technology education than giving pre-service teachers practice opportunities, and technology training was limited to these two courses; therefore, the knowledge and skills gained from this process remain isolated and unused.

The findings of Bullock's [38] study suggested that a combination of effective mentoring and modeling, clear expectations, easy access to technology and technology support and positive experiences with technology in the classroom will enable pre-service teachers to practice using technology on a regular basis. Although some may have built relevant knowledge and beliefs from previous experiences, pre-service teachers may not understand how these ideas translate into practice; thus, they need to see examples of what this kind of teaching looks like in practice [39]. Therefore, pre-service teachers need to be provided with authentic learning experiences using technology throughout their teacher preparation programs: to see a connection between the words and actions of university faculty regarding the importance of technology integration; to see the relevance of technological skills to their content areas; and to have sufficient time to retain and reflect on the technology skills to which they have been exposed [35]. Understanding how technology integration knowledge develops within a specific teacher preparation program will no doubt be a critical planning component for effectively preparing students for increasing technology integration [40].

### *1.3. TPACK Framework*

According to Koehler and Mishra [13], at the heart of good teaching with technology are three core components: content, pedagogy and technology, plus the relationships among and between them. These three knowledge bases (content, pedagogy and technology) form the core of the technology, pedagogy and content knowledge framework. TPACK is viewed as a dynamic framework describing the knowledge that teachers must rely on to design and implement curriculum and instruction while guiding their students' thinking and learning with digital technologies in various subjects [41]. Koehler, Mishra and Yahya [42] argued that knowledge of technology cannot be treated as context-free and that good teaching requires an understanding of how technology relates to the pedagogy and content. This approach to technology integration was upon content-based learning activities, rather than the affordances and constraints of educational technologies that can support learning activities for students [43].

The term TPACK began to gain widespread popularity in 2006 after Mishra and Koehler's study outlining the model and describing each of the central constructs. TPACK was called "TPCK" in the literature until 2008, when some in the research community proposed using the more easily spoken term TPACK [44]. Koehler and Mishra [45] introduced technological pedagogical content knowledge (TPCK) as a way of representing what teachers need to know about technology and argued for the role of authentic design-based activities in the development of this knowledge.

The TPACK framework builds on Shulman's (1986, 1987) descriptions of pedagogical content knowledge [13]. Shulman recognized the need for a more coherent theoretical framework concerning what teachers should know and be able to do, including what content knowledge they needed to possess and how this knowledge is related to that of good teaching practices [46]. Mishra and Koehler [15] proposed a conceptual framework for educational technology by building on Shulman's formulation of pedagogical content knowledge and extend it to the phenomenon of teachers integrating technology into their pedagogy. Therefore, according to Koehler and Mishra [13], TPACK allows teachers, researchers and teacher educators to move beyond oversimplified approaches that treat technology as an "add-on" instead to focus again, and in a more ecological way, on the connections among technology, content and pedagogy as they play out in classroom contexts. Figure 1 shows how the TPACK framework is structured.

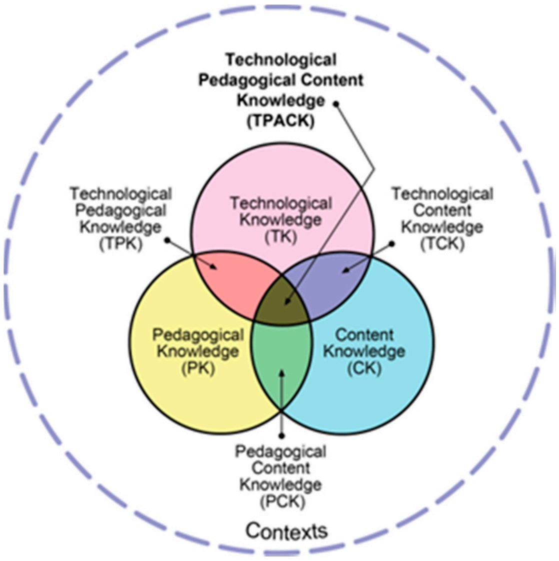


**Figure 1.** The TPACK framework [47].

As Schmidt, Baran, Thompson, Mishra, Koehler and Shin [48] stated, TPACK is a useful frame for thinking about what knowledge teachers must have to integrate technology into teaching and how they might develop this knowledge. Using TPACK as a framework for measuring teaching knowledge could potentially have an impact on the type of training and professional development experiences that are designed for pre-service teachers [48].

## 2. Experimental Section

### *2.1. Participants and Sampling*

Participants of this study were 491 elementary pre-service teachers who attended the summer semester at Pamukkale University in southwestern Turkey. The numbers of the participants for each of the variables are: 341 female, 150 male; 129 between the ages of 18–20, 323 between the ages of 21–23, 29 between the ages of 24–26, 10 between the ages of 27–29; 294 day instruction, 197 night instruction; 175 had field experience, 316 do not have field experience; 38 freshman, 201 sophomore, 83 junior, 169 senior; 178 primary, 14 preschool, 93 counselor, 8 computer, 13 literacy, 56 mathematics, 36 social, 12 music, 30 foreign language, 23 visual arts and 28 science area of specialization. The researchers used G-Power statistical software to determine the minimum sampling size.

### *2.2. Survey Instrument*

The "Survey of Pre-service Teachers' Knowledge of Teaching and Technology" developed by Schmidt *et al.* [48] was used in this study (see the Appendix). The researchers not only used all of the variables from the original version of the survey instrument, but also added one more variable for this study, which is the kind of instruction. Pamukkale University has day and night instruction options, and generally, course instructors are different for day and night education. Therefore, it is inquired whether different instructors design the courses differently.

This TPACK survey consists of 46 items in seven subscales, like technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and technology pedagogy and content knowledge (TPACK). Researchers are free to use the TPACK survey with the permission of the authors [48]. Therefore, the first author of this study sent an email to the first author of the survey to inform them about this study.

Kaya and Dag [49] adapted the TPACK survey into Turkish and investigated its factor structure through exploratory and confirmatory factor analysis. Their results showed that the factor structure of the Turkish version of the survey was similar to the original version. Furthermore, the factor analysis results showed a good model fit. Therefore, based on their results, Kaya and Dag [49] concluded that the TPACK survey was appropriate for the Turkish culture. In this study, the Cronbach alpha reliability results of subscales were between 0.70 and 0.93. This result is aligned with both the original version of the survey Cronbach alpha results (between 0.78 and 0.93) and Kaya and Dag's [49] results (between 0.77 and 0.88).

### *2.3. Data Collection*

The researchers collected the data at the end of the summer semester of Pamukkale University in 2013. At the beginning of the survey, participants were informed that neither their identity would be released nor will their participation affect their grades. The survey was conducted in the classrooms, and it took approximately 45 min.

### *2.4. Data Analysis*

Data were analyzed using the Statistical Program for Social Sciences Version 20. After considering skewness and kurtosis results to check the normality assumption for each of the sub-scales, the results showed that there was not any violation of the normality assumption. The researchers also checked homogeneity, independence and linearity assumptions for appropriate analyses. There was not any violation detected. An independent *t*-test and one-way analysis of variance (ANOVA) were used to examine the relationships between each of the TPACK subscales and demographic features, like gender, age, area of specialization, year of study, kind of instruction (day or night education) and field experience. The backward regression analysis method was used to examine if TK, PK and CK significantly contributed to pre-service teachers' TPACK development. To deal with the missing values in the data, the listwise method was used.

## 3. Results and Discussion

### *3.1. TPACK per Gender*

An independent-samples *t*-test was conducted to compare knowledge of teaching and technology in all sub-domains of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK) for female and male pre-service teachers. Out of the 491 teachers, 341 were female, and 150 were male. The results showed that there was a significant difference for the TK between female (M = 20.767, SD = 3.914) and male (M = 22.623, SD = 4.114) students; $t(480) = -4.707$, $p = 0.000$; however, it did represent a small-sized effect $r = 0.21$. Furthermore, there was no significant difference between perceptions of female and male students in terms of CK, PK, PCK, TCK, TPK or TPACK (Table 1).

**Table 1.** TPACK perceptions of pre-service teachers in terms of gender.

| | **Female** | | **Male** | | | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | ***t*** | **df** | ***p*** |
| **TK** | 20.767 | 3.914 | 22.623 | 4.114 | −4.707 | 480 | 0.000 |
| **CK** | 40.567 | 6.737 | 40.578 | 6.286 | −0.017 | 443 | 0.987 |
| **PK** | 26.415 | 4.766 | 26.315 | 4.570 | 0.193 | 462 | 0.847 |
| **PCK** | 13.256 | 3.024 | 13.276 | 2.547 | −0.069 | 316.035 | 0.941 |
| **TCK** | 12.764 | 3.091 | 12.848 | 3.021 | −0.270 | 451 | 0.787 |
| **TPK** | 32.848 | 5.550 | 33.524 | 5.270 | −1.243 | 460 | 0.214 |
| **TPACK** | 13.019 | 3.292 | 12.751 | 3.079 | 0.777 | 440 | 0.437 |

### *3.2. TPACK per Age*

To analyze if there were significant differences among pre-service teachers' age differences and their perceptions about all sub-domains of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK), one-way variance analysis was used for each sub-domain and age category. Results indicated that there were no significant differences among all of these sub-domains of TPACK (Table 2). In this regard, it was found that age groups were not a significant factor for the TPACK perceptions of pre-service teachers. Since these results were statistically insignificant, multiple comparisons of groups and the measure of effect size were not mentioned.

### *3.3. TPACK per Area of Specialization*

Analysis of variance was used for each sub-domain and educational program, such as primary education, preschool education, mathematics education, *etc.*, to determine if there were significant differences among the educational programs that pre-service teachers attend and their perceptions about all sub-domains of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK). Results showed that there were significant differences among pre-service teachers' perceptions in all of the sub-domains, except PK.

**Table 2.** TPACK perceptions of pre-service teachers in terms of age.

| | | SS | df | MS | F | *p* |
|---|---|---|---|---|---|---|
| **TK** | Between groups | 25.893 | 3 | 8.631 | 0.522 | 0.667 |
| | Within groups | 7896.306 | 478 | 16.519 | | |
| **CK** | Between groups | 268.659 | 3 | 89.553 | 2.074 | 0.103 |
| | Within groups | 19,000.035 | 440 | 43.182 | | |
| **PK** | Between groups | 107.308 | 3 | 35.769 | 1.620 | 0.184 |
| | Within groups | 10,133.789 | 459 | 22.078 | | |
| **PCK** | Between groups | 32.704 | 3 | 10.901 | 1.313 | 0.270 |
| | Within groups | 3752.761 | 452 | 8.303 | | |
| **TCK** | Between groups | 21.289 | 3 | 7.096 | 0.754 | 0.520 |
| | Within groups | 4216.322 | 448 | 9.411 | | |
| **TPK** | Between groups | 112.666 | 3 | 37.555 | 1.257 | 0.289 |
| | Within groups | 13,653.113 | 457 | 29.876 | | |
| **TPACK** | Between groups | 30.696 | 3 | 10.232 | 0.982 | 0.401 |
| | Within groups | 4543.523 | 436 | 10.421 | | |

Since the assumption of the homogeneity of variance was not met for CK, PCK, TCK and TPACK, we used Welch's adjusted F ratio for: CK, $F(10,62.434) = 4.666$, $p < 0.000$; PCK, $F(10,67.548) = 5.043$, $p < 0.000$; TCK, $F(10,62.109) = 7.334$, $p < 0.000$; and TPACK, $F(10,64.159) = 10.278$, $p < 0.000$; all were significant at the 0.05 alpha level. In addition, the Games–Howell *post hoc* follow-up procedure was conducted to test the difference between all unique pairwise comparisons. The Games–Howell test results showed that in terms of CK, the self-efficacy of primary education (42.391) pre-service teachers was significantly higher than mathematics (37.603), social science (38.161) and foreign language (36.667) education pre-service teachers' self-efficacy. With respect to PCK, the self-efficacy of primary (14.073) and science (14.143) education pre-service teachers was significantly higher than mathematics (11.679) education pre-service teachers' self-efficacy. Based on TCK, it is found that self-efficacy of primary education (13.921) pre-service teachers was significantly higher than mathematics (11.574), social science (11.879), counselor (11.914) and foreign language (10.600) education pre-service teachers' self-efficacy. In addition, in terms of TCK, science education (14.321) pre-service teachers had also significantly higher self-efficacy than mathematics, social science, counselor and foreign language education pre-service teachers' self-efficacy. Furthermore, primary education (14.375) pre-service teachers' self-efficacy about TPACK was higher than mathematics (11.720), social science (11.853), counselor (11.254) and foreign language (10.200) education pre-service teachers' self-efficacy. Additionally, considering TPACK, it is found that the self-efficacy of science education (14.482) pre-service teachers was significantly higher than mathematics, social science, counselor and foreign language education pre-service teachers' self-efficacy.

There was a significant difference among the perceptions of pre-service teachers based on TK, $F(10,465) = 3.955$, $p < 0.000$. According to the results, it was found that primary (21.875), visual arts (23.636), science (22.964) and computer (24.875) education pre-service teachers had significantly higher self-efficacy than social science (19.161) education pre-service teachers' self-efficacy. Further, visual arts (23.636) education pre-service teachers had higher self-efficacy than mathematics (20.370) and counselor (20.570) education pre-service teachers' self-efficacy in terms of TK. Additionally, computer and technology education (24.875) pre-service teachers had the highest arithmetic mean of TK among the other education program pre-service teachers. Finally, there was a significant difference among pre-service teachers' self-efficacy based on TPK, $F(10,445) = 3.446$, $p < 0.000$. Primary (33.904), visual arts (35.174) and science (35.250) education pre-service teachers had significantly higher self-efficacy than counselor (30.987) education pre-service teachers' self-efficacy.

### *3.4. TPACK per Year of Study*

One-way variance analysis was used for sub-domains and the year of study to analyze if there were significant differences among pre-service teachers' year of study and their perceptions about all sub-domains of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK). Results indicated that there were significant differences in terms of PCK and TCK (Table 3). However, they represented small-sized effects, $r_{(PCK)} = 0.151$ and $r_{(TCK)} = 0.107$. It is found that based on PCK, the self-efficacy of senior (13.799) pre-service teachers was significantly higher than sophomore (12.891) pre-service teachers. Moreover, with respect to TCK, junior (13.473) pre-service teachers had significantly higher self-efficacy than sophomore (12.309) pre-service teachers.

**Table 3.** TPACK perceptions of pre-service teachers in terms of year of study.

| | | SS | df | MS | F | *p* |
|---|---|---|---|---|---|---|
| **TK** | Between groups | 40.155 | 3 | 13.385 | 0.811 | 0.488 |
| | Within groups | 7900.843 | 479 | 16.494 | | |
| **CK** | Between groups | 190.454 | 3 | 63.485 | 1.468 | 0.223 |
| | Within groups | 19,114.299 | 442 | 43.245 | | |
| **PK** | Between groups | 121.214 | 3 | 40.405 | 1.840 | 0.139 |
| | Within groups | 10,122.880 | 461 | 21.959 | | |
| **PCK** | Between groups | 87.196 | 3 | 29.065 | 3.560 | 0.014 |
| | Within groups | 3706.306 | 454 | 8.164 | | |
| **TCK** | Between groups | 91.701 | 3 | 30.567 | 3.307 | 0.020 |
| | Within groups | 4159.420 | 450 | 9.243 | | |
| **TPK** | Between groups | 144.658 | 3 | 48.219 | 1.619 | 0.184 |
| | Within groups | 13,674.767 | 459 | 29.793 | | |
| **TPACK** | Between groups | 40.858 | 3 | 13.619 | 1.311 | 0.270 |
| | Within groups | 4549.968 | 438 | 10.388 | | |

### *3.5. TPACK per Kind of Instruction (Day and Night Classes)*

An independent-samples *t*-test was conducted to compare all sub-domains of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK) perceptions of pre-service teachers attending day or night classes. The results indicated that there were no significant differences among all of these sub-domains of TPACK (Table 4). In this regard, it was found that the kind of instruction was not a significant factor for the TPACK perceptions of pre-service teachers. Since these results were not statistically significant, comparisons of groups and the measure of effect size were not mentioned.

**Table 4.** TPACK perceptions of pre-service teachers in terms of kind of instruction.

| | Day | | Night | | | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | ***t*** | **df** | ***p*** |
| **TK** | 21.5401 | 4.14733 | 21.0105 | 3.93365 | 1.396 | 476 | 0.163 |
| **CK** | 40.5390 | 6.85098 | 40.5000 | 6.16299 | 0.061 | 439 | 0.952 |
| **PK** | 26.5231 | 4.69958 | 26.0615 | 4.70018 | 1.027 | 458 | 0.305 |
| **PCK** | 13.1957 | 2.82352 | 13.3256 | 2.99099 | −0.464 | 451 | 0.643 |
| **TCK** | 12.6836 | 3.04317 | 12.9138 | 3.09923 | −0.775 | 447 | 0.439 |
| **TPK** | 33.1594 | 5.56319 | 32.8187 | 5.34811 | 0.651 | 456 | 0.515 |
| **TPACK** | 12.8229 | 3.25775 | 13.0361 | 3.18689 | −0.670 | 435 | 0.503 |

### *3.6. TPACK per Field Experience*

After conducting an independent *t*-test to determine if having field experience makes a difference in pre-service teachers' perceptions in terms of TPACK (TK, CK, PK, PCK, TCK, TPK, TPACK), it was found that there was a significant difference between pre-service teachers' perceptions who had field experience and those that did not have experience. Pre-service teachers who had field experience revealed greater CK (M = 42.268, SD = 6.593) than pre-service teachers who did not (M = 39.588, SD = 6.400), $t(441) = 4.209$, $p = 0.000$, $r = 0.197$; greater PK (M = 27.256, SD = 4.457) than pre-service teachers who did not (M = 25.909, SD = 4.711), $t(460) = 2.997$, $p = 0.003$, $r = 0.138$; greater PCK (M = 14.219, SD = 2.794) than pre-service teachers who did not (M = 12.756, SD = 2.794), $t(453) = 5.333$, $p = 0.000$, $r = 0.243$; greater TCK (M = 13.321, SD = 3.092) than pre-service teachers who did not (M = 12.497, SD = 3.010), $t(449) = 2.751$, $p = 0.006$, $r = 0.129$; greater TPACK (M = 13.824, SD = 3.158) than pre-service teachers who did not (M = 12.444, SD = 3.174), $t(437) = 4.347$, $p = 0.000$, $r = 0.204$.

### *3.7. Predicting the Contribution of TK, CK and PK to TPACK*

According to the results, TK, CK and PK were significantly and positively correlated with TPACK. Additionally, correlations among TK, CK and PK were also significant ($p = 0.000$). All of these correlations were significant when we considered Bonferroni adjustment to maintain our risk of Type I error. Furthermore, CK was the one that had a strong correlation with TPACK ($r = 0.523$, $p = 0.000$). While PK had a moderate correlation ($r = 0.397$, $p = 0.000$), TK had a small correlation with TPACK ($r = 0.263$, $p = 0.000$).

On the other hand, considering the regression coefficients, it is found that while CK and PK were significantly contributing to the model, TK did not contribute significantly (Table 5). The total model predicted 31% of the variation in TPACK, which was significant ($p = 0.000$).

**Table 5.** Regression model.

| | **β** | **SE** | ***p*** |
|---|---|---|---|
| **TK** | 0.012 | 0.037 | 0.750 |
| **CK** | 0.207 | 0.023 | 0.000 |
| **PK** | 0.147 | 0.033 | 0.000 |
| $\mathbf{R^2}$ | 0.31 | | 0.000 |
| **F** | 61.041 (df = 3407) | | |

## 4. Discussion and Conclusions

This study investigated TPACK perceptions of pre-service teachers according to the sub-domains of the TPACK framework. Our literature review revealed that there was much existing research about pre-service teachers' TPACK knowledge; however, this research was different from all existing research based on its scope. This comprehensive quantitative research is important to understand the insight of pre-service teachers' TPACK self-efficacy and to improve TPACK development of pre-service teachers.

The results of this study showed that male pre-service teachers' TK self-efficacy is significantly higher than female teacher candidates'. This result aligned with the Erdogan and Sahin's [50] research results that significant differences are found between male and female pre-service teachers' TPACK in favor of male students. Moreover, we found that the age variable was not a significant factor for the TPACK perceptions of pre-service teachers. This result supported the results of Koh, Chai and Tsai's [51] study that age did not have a significant influence on TPACK. On the other hand, Lee and Tsai [52] found that older and more experienced teachers had lower levels of self-efficacy with respect to their web-based TPACK.

Furthermore, it is determined that pre-service teachers' year of study had an impact on the TPACK of teacher candidates in terms of their perceptions of PCK and TCK. Besides, senior students considered their PCK significantly higher than sophomores, and junior students evaluate their TCK significantly higher than sophomores. The underlying reasons for these results are open for further research; however, it is assumed that one of the reasons might be because senior and junior students have more pedagogical and content-related course experiences than sophomore students. Aligning with this result, there was existing research showing that teachers' perceptions of the TPACK domains were varying based on their years of experiences. Chuan and Ho [53] stated that teachers who had more years of experience had higher-level perceptions on some TPACK sub-domains. Besides, Hew and Brush [12] stated that teachers' attitudes and beliefs were influenced by teacher's knowledge and skills, resources and institution and that those attitudes and beliefs directly influence teachers' integration of technology.

When we considered if day or night instruction had an impact on pre-service teachers' TPACK perceptions, it was found that the kind of instruction did not have any effect on pre-service teachers' TPACK. Therefore, it was concluded that this might be because technology-, pedagogy- and content-related instruction had determined standards by the Council of Higher Education of Turkey; therefore, instructors designed courses accordingly.

Although, there was no significant difference among kinds of instruction, it was found that there was a significant difference among pre-service teachers' educational programs. Based on the results, primary education pre-service teachers had significantly higher self-efficacy in almost all TPACK domains than math and social science teacher candidates. Considering the educational programs variable, Erdogan and Sahin [50] concluded that elementary mathematics teacher candidates had significantly higher TPACK than secondary mathematics teacher candidates. Further, they explained that one of the reasons why elementary mathematics pre-service teachers had significantly higher TPACK might be because the Department of Elementary Mathematics Education offers more information on TPACK because of its selective courses and curriculum. In this sense, it is presumed that the reason that primary education pre-service teachers had significantly higher self-efficacy in almost all TPACK domains might be because primary education pre-service teachers are getting educated to teach several courses. This notion needs to be studied specifically before making any assertions.

Moreover, when we analyzed the effect of having field experience on teacher candidates' TPACK, it was found that there were significant differences in almost all sub-domains of TPACK. Pamuk [4] concluded that PCK of pre-service teachers should be supported by actual teaching experiences. He claimed that TPACK was based on the PCK concept. In favor of Pamuk's claim, Niess [7] stated that at the beginning of their student teaching experience, the student teachers naturally focused on their own teaching and were less likely to think about their students' understandings, thinking and learning. Hence, we can assume that pre-service teachers tend to focus first on their own content and pedagogical knowledge. We may support this assertion by our regression result considering PK and CK significantly contributing more to pre-service teachers' TPACK. In addition, aligning with the literature about integrating technology into instruction that we mentioned before, the results of pre-service teachers' TK gives rise to the idea that pre-service teachers are having difficulty connecting their technology knowledge with pedagogy- and content-related domains.

Finally, although TK, PK and CK are significantly correlated with TPACK, the regression model showed that while CK and PK contributed significantly to pre-service teachers' TPACK model, TK was not a significant predictor of TPACK. In this sense, our result is different than the related research of Chai, Koh and Tsai [54], which concluded that TK, PK and CK were all significant predictors of pre-service teachers' TPACK.

Additionally, regression results also showed that the model could only explain 31 percent of the variance in TPACK. Consequently, it is found that there are other factors affecting pre-service teachers' TPACK development for our sample, which is not captured in the model; therefore, the researchers will further investigate the reasons for this result.

In conclusion, this study found that CK had the largest impact on TPACK. In addition, based on the regression analysis, we can infer that pre-service teachers are not able to combine their technology knowledge with their content and pedagogy knowledge. Thus, by taking this significant contribution into account technology, content- and pedagogy-related courses should be redesigned as necessary and the possible solutions to help pre-service teachers to link technology knowledge with content and pedagogy knowledge for future possible improvement of TPACK for pre-service teacher education investigated.

## Author Contributions

This paper was a result of collaboration between the two authors. Duygu Cetin-Berber came up with the idea. Ali Riza Erdem collected the data and ran the initial analyses. Duygu Cetin Berber finalized the data analyses. Both authors contributed to the writing and editing of the manuscript. Both authors have read and approved the final manuscript.

## Appendix

**Table A1.** Survey of pre-service teachers' knowledge of teaching and technology.

| | **Strongly Disagree** | **Disagree** | **Neither Agree or Disagree** | **Agree** | **Strongly Agree** |
|---|---|---|---|---|---|
| TK (Technology Knowledge) | | | | | |
| 1. I know how to solve my own technical problems. | | | | | |
| CK (Content Knowledge) Mathematics | | | | | |
| 7. I have sufficient knowledge about mathematics. | | | | | |
| PK (Pedagogical Knowledge) | | | | | |
| 19. I know how to assess student performance in a classroom. | | | | | |
| PCK (Pedagogical Content Knowledge) | | | | | |
| 26. I can select effective teaching approaches to guide student thinking and learning in mathematics. | | | | | |
| TCK (Technological Content Knowledge) | | | | | |
| 30. I know about technologies that I can use for understanding and doing mathematics. | | | | | |
| TPK (Technological Pedagogical Knowledge) | | | | | |
| 34. I can choose technologies that enhance the teaching approaches for a lesson. | | | | | |
| TPACK (Technology Pedagogy and Content Knowledge) | | | | | |
| 43. I can teach lessons that appropriately combine mathematics, technologies and teaching approaches. | | | | | |

## Conflicts of Interest

The authors declare no conflict of interest.

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