Examining Preservice Teachers' TPACK-21 Efficacies with Clustering Analysis in Terms of Certain Variables

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ABSTRACT

The purpose of this study was to determine the differences between preservice teachers' 21st century techno-pedagogical content knowledge (TPACK-21). The study group included 254 preservice teachers from the departments of Science Teaching and Mathematics Teaching at a state university in Turkey. In order to determine the preservice teachers' strong and weak points in terms of TPACK-21 and to reveal the differences between them in terms of their gender, computer use efficacies and Internet use frequencies, the clustering analysis method was used. For the purpose of confirming the evident difference between the TPACK-21 variables, one-way ANOVA was applied, and the effect sizes were determined (η2). It was found that for all the variables, there were significant differences between the clusters. Also, Bonferroni post hoc analysis conducted for the confirmation of the clusters revealed significant differences between the clusters for each factor influential on the students' TPACK-21 perceptions.

Keywords: TPACK; 21st century skills, k-means

INTRODUCTION

Since technology became an indispensable part of daily life, individuals have been expected to have technology literacy in the 21st century societies. Technology not only supports daily life but also contributes to teaching how to learn Voogt, Tilya, & Van den Akker, 2009; Williams, Linn, Ammon, & Gearhart, 2004). A successful teaching and learning process is possible with the integration of technology into education. Teachers play a key role in using technology in education (Instefjord and Munthe, 2017; Lawless & Pellegrino; 2007; Sang, Valcke, Van Braak & Tondeur; 2010). For the integration of technology into education, teachers should have computer literacy (Sang et.al.; 2010; Uerz, Volman & Kral, 2018; Hobbs & Tuzel, 2017). Use of technology in education facilitates the teaching activities both for teachers and for students. Li and Keller (2018) point out that motivation has a direct relationship with technology-based instruction for students and that their academic achievement increases as their motivation increases. Vongkulluksn, Xie, and Bowman (2018) state that teachers using technology spend more time on teaching in class. In addition, the importance of the relationship between technology literacy and education is emphasized by Mishra and Koehler (2006) with their model of Technology Pedagogical Content Knowledge (TPACK).

TPACK Framework and Its Dimensions

Today, teachers are supposed to have such efficacies as the 21st century skills to achieve an effective technology integration in line with the developing technology (Cox, 2008). In addition, while teachers and preservice teachers include technology integration in their classes parallel to these new technologies, they have to go through a dynamic and complex process which includes technology as well as pedagogy and content knowledge (Mishra & Koehler, 2006). This is important because this complex process since is used in learning and teaching and has become a part of teaching. The International Society for Technology in Education (ISTE, 2002) defines technology integration as the integration of technology in the education process with the context of content area. This definition also includes the difficulties in the integration process. The European Commission (2017) points out that in terms of teachers' efficacies, a teacher should have information/data literacy skills, use technologies involving communication and interaction, produce digital contents appropriate to the course, solve the probable problems related to technology and have enough knowledge about security technologies.

TPACK was developed as a conceptual framework by including technological knowledge in the framework of "pedagogical content knowledge" put forward by Shulman (1986). By broadening Shulman's framework, Mishra and Koehler (2006) adds technology knowledge as a separate area of effect and point out that especially digital technologies have changed (or are likely to change) the quality of classrooms. The TPACK framework defines the knowledge that teachers need for teaching with technology (Niess, 2008). This framework basically includes seven areas that can be categorised.

Content Knowledge (CK): This area covers teachers' knowledge about the subjects to be taught or learned. It is quite different from the content to be taught at secondary schools and from the content to be presented in a postgraduate seminar in the field of art education or computer sciences. As mentioned by Shulman (1986), this area includes knowledge about realities, concepts, theories, laws, organizational frameworks, evidence and proof as well as about applications and methods for constructing this knowledge.

Pedagogical Knowledge (PK): This area sheds light on teachers' approaches to teaching and learning, on the related procedures and on the understandings related to the applications and methods. It covers all the values related to the educational goals. This knowledge also includes the way students learn, general class management skills, lesson planning, assessment of students and comprehension skills (Koehler & Mishra, 2009).

Technology Knowledge (TK): This area gathers technological tools, applications and sources and is related to the knowledge of how to integrate this technology into the teaching-learning process. This knowledge is necessary for effective and productive use of technology in the work place and in daily life

(Koehler & Mishra, 2009). With the spread of the Internet and personal computers, the knowledge of technology has gained more importance.

Pedagogical Content Knowledge (PCK): This area developed by Shulman in a way to include the pedagogical knowledge and concepts necessary for teaching a specific content. PCK is the area which allows integrating the curriculum and the connections between assessment and pedagogy into the teaching and learning process (Koehler & Mishra, 2009).

Technological Content Knowledge (TCK): This area is related to understanding how technology and content (subject) influence or restrict one another. Teachers are supposed to be specialized in the subjects they teach. Moreover, they are supposed to understand how to develop the content with the application of certain educational technologies. Teachers should now only know how technology influences the lessons in the teaching process and how to change the technology if necessary but also learn how to use the most appropriate technological methods (Koehler & Mishra, 2009).

Technological Pedagogical Knowledge (TPK): This knowledge is the insight related to how teaching and learning may change when certain technologies are used appropriately. This area refers to understanding the relationships and restrictions that will appear when appropriate pedagogical designs and strategies are used with technological tools (Koehler & Mishra, 2009).

Techno-Pedagogical Content Knowledge (TPACK): This area covers the responses to the questions of ”How can I most effectively gather pedagogy and technology to teach a certain concept” and “How can I use technology in my classes” (Fransson & Holmberg, 2012; Hewitt, 2008). In addition, TPACK constitutes the basis of effective teaching with the use of technology. This area includes the pedagogical designs which require strategical and meaningful use of technology to teach technological contents and related concepts. Also, this area refers to the knowledge about how to use technology to facilitate learning and to cope with the problems that students face especially in learning complicated concepts.

21st Century Skills

With the spread of Information and Communication Technologies (ICT) in our daily life, our way of working has changed fundamentally. As a result of the increasing use of digital technologies, our social culture has started to develop. Thanks to digital technologies, new areas of efficacies and concepts have appeared. In order to apply these new efficacies in our lives, schools, teachers and students are supposed to have such skills as cooperation and communication, which will facilitate creative and innovative thinking in daily life (Griffin, Care & McGaw, 2012; Lai & Viering, 2012). A new concept of educational standards and evaluation has a key role in completing the needed transformations. Education faculties have an important place in training preservice teachers in a way to get the 21st century skills (Mäkitalo-siegl, Ahonen, & Häkkinen, 2014).

The 21st century partnership defines the efficacies that individuals should have in three main frameworks: (1) Innovation skills related to learning such as creativity, innovation, critical thinking, problem solving, communication and cooperation, (2) information media technology skills including information literacy, media literacy and ICT literacy and (3) life and career skills related to flexibility, adaptability, enterprises, self-evaluation, social and inter-cultural skills, productivity, accountability, leadership and responsibility (Lai & Viering, 2012; 21st Century Skills, 2006). The National Research Council defines the 21st century skills as follows: (1) cognitive skills including critical thinking, non-routine problem solving and systematic thinking, (2) interpersonal skills such as complex communication, social skills, team work, cultural sensitivity and coping with variability and (3) personal skills including personal management, time management, personal development, personal arrangement, adaptability and executive functions (Lai & Viering, 2012). The effort to determine the common points in conceptualizing the 21st century skills or efficacies has always drawn scientists' attention. It is seen that most of these frameworks include ICT-related efficacies, cooperation, communication and social and cultural competencies. In addition, most of them include skills related to creativity, critical thinking and problem solving problem (Voogt & Roblin, 2012). Also, some of the frameworks cover self-arrangement efficacies related to productivity and responsibility (Voogt & Roblin, 2012). Although the 21st century skills are defined as certain concepts, most of the defined skills can be regarded as general skills that have special importance in digital contexts (Van Laar, Van Deursen, Van Dijk, & De Haan, 2017).

RESEARCH METHOD

Research Sample

The study group included 254 preservice teachers from the departments of Science Teaching and Mathematics Teaching at the education faculty of a state university in Turkey.

Purpose of the Study

The present study aimed to determine preservice teachers' PTACK-21 self-efficacies with the help of the clustering analysis method. In line with this purpose, the following research questions were directed in the study:

1. Is there a difference between the preservice teachers' TPACK-21 self-efficacies?
2. Is there a difference between the preservice teachers' TPACK-21 self-efficacy perceptions with respect to their gender?
3. Is there a difference between the preservice teachers' TPACK-21 self-efficacy perceptions with respect to their computer use efficacies?
4. Is there a difference between the preservice teachers' TPACK-21 self-efficacy perceptions with respect to their Internet use frequencies?

Clustering Analysis

Clustering analysis, which is defined as dividing objects into natural groups depending on their similarities, is used to reveal the previously unknown relationships between objects, to decrease the number of dimensions and to determine the outliers (Ferreira & Hitchcock, 2009). Clustering analysis basically falls into two groups: hierarchical clustering analysis and non-hierarchical clustering analysis. In the present study, k-means, which is the most common method in non-hierarchical clustering analysis was used. MacQueen suggested this method in 1967 to divide a universe with N number of dimensions into k number of clusters (MacQueen, 1967). In the K-means algorithm, k number of groups each of which is made up of a random point are included in the clustering. Following this, each universe is assigned to the group with the closest mean. After a universe is added to a group, the mean for that group is re-calculated considering the new universe (MacQueen, 1967).

Data Collection Tool

The TPACK-21 questionnaire used in the study included 38 6-point Likert-type items (1 = I need more knowledge about the subject; 6 = I have strong knowledge about the subject). The areas of pedagogical content knowledge (PCK21) and techno-pedagogical content knowledge (TPK) were measured using two perspectives by the developers of the TPACK-21 questionnaire. In the first phase, the general statements do not depend on a specific pedagogical application or on theories about learning. These statements are appropriate to previous TPACK evaluation tools like pedagogical and technological knowledge (Schmidt, Baran, Thompson, Mishra, Koehler, & Shin, 2009). The second phase includes pedagogical statements based on the 21st century skills (e.g. cooperation, creative thinking and problem solving) (Voogt and Roblin, 2012). In the TPACK-21 scale, the 21st century skill approaches were selected (Valtonen, Sointu, Mäkitalo-Siegl, & Kukkonen, 2015). The TPACK-21 scale was obtained by adding the number ’21’ to the sub-dimensions measuring the 21st century skills. The questionnaire focuses on TPACK from nine perspectives: pedagogical knowledge (seven items: facilitating discussions among 2-5 students and facilitating reflective thoughts of 2-5 students “group work”), technological efficacy (four items: “I am familiar with new technologies and their features”, content knowledge about science (four items: “I can understand basic scientific theories and concepts”), technological pedagogical knowledge (three items: “I can choose the best methods possible for science teaching”), technological pedagogical knowledge 21 (six items: “While teaching, I know how to use ICT as a tool for sharing ideas and thinking together”), pedagogical content knowledge 21 (six items: “While teaching science, I know how to guide students to develop the problem solving skills of groups of 2-5 students”, technological content knowledge (four items: “I can understand the ICT applications used by experts in science”) and TPACK (seven items: “I know how to use information technologies in science as a tool for sharing ideas and thinking together”). The initial studies on the TPACK-21 scale demonstrated an acceptable level of reliability and validity as a result of the exploratory factor analysis (Valtonen et.al., 2015) and confirmatory factor analysis (Valtonen, Sointu, Kukkonen, Kontkanen, Lambert, & Mäkitalo-Siegl, 2017). The Cronbach alpha values for the reliability of the scale were as follows: PK21 (α = .93), CK (α = .92), TK (α = .88), PCK21 (α = .95), TPK21 (α = .95), TCK (α = .89) and TPACK-21 (α = .96).

FINDINGS

This study aimed to reveal the differences between the science and mathematics preservice teachers in terms of the areas of 21st century technological pedagogical content knowledge. Table 1 presents the mean scores, standard deviations and correlations in relation to the variables used in the study. The results of the descriptive statistics revealed that the preservice teachers had the lowest mean score in TCK (M = 2,950, SD = 1,186) and the highest mean score in PK21 (M = 3,785, SD = 1,80). According to the results, the scores related to the other variables were slightly higher than the mean: CK (M=3,200, SD=1,316), TK (M=3,130; SD=1,170); PCK21 (M=3,450; SD=1,133); TPK21 (3,266; SD=1,128); TPACK21 (M=3,039; SD=1,125). There were positive significant correlations between the correlation matrix variables. The TPACK-21 scale correlations ranged between r = ,313 and r = ,788, and there were significant relationships between the factors. Based on this, it could be stated that the factors constituting TPACK-21 did not overlap one another but correlated with each other.

Table 1. Mean Scores, Standard Deviations and Correlations for the TPACK-21 Scale

N=254	M	SD	PK21	CK	TK	PCK21	TPK21	TCK	TPACK21
PK21	3,785	1,080	1						
CK	3,200	1,316	,313**	1					
TK	3,130	1,170	,423**	,516**	1				
PCK21	3,450	1,133	,593**	,406**	,638**	1			
TPK21	3,266	1,128	,542**	,633**	,554**	,621**	1		
TCK	2,950	1,186	,338**	,543**	,579**	,490**	,718**	1	
TPACK21	3,039	1,125	,462**	,579**	,592**	,656**	,788**	,764**	1

Note: All the coefficients were significant at $p < .01$.

In the K-means cluster analysis, the participants were divided into three groups depending on their responses to the TPACK-21 scale. For each variable, the mean in the cluster was determined, and one-way ANOVA was conducted to confirm the effective difference between the clusters. Table-2 shows the p-value and the effect sizes (η^2). There were significant differences between the clusters in terms of all the variables ($p <.01$). The intensity of these differences is emphasized with the high effect size values. When the effect size was examined, it was seen that the factors with a high effect size among the clusters were TPACK21 and TPK21. In addition, the Bonferroni post hoc analysis revealed significant differences between all the clusters depending on each factor influential on the preservice teachers' acceptance. Figure 1 presents the mean of the cluster centers formed as a result of the k-means analysis.

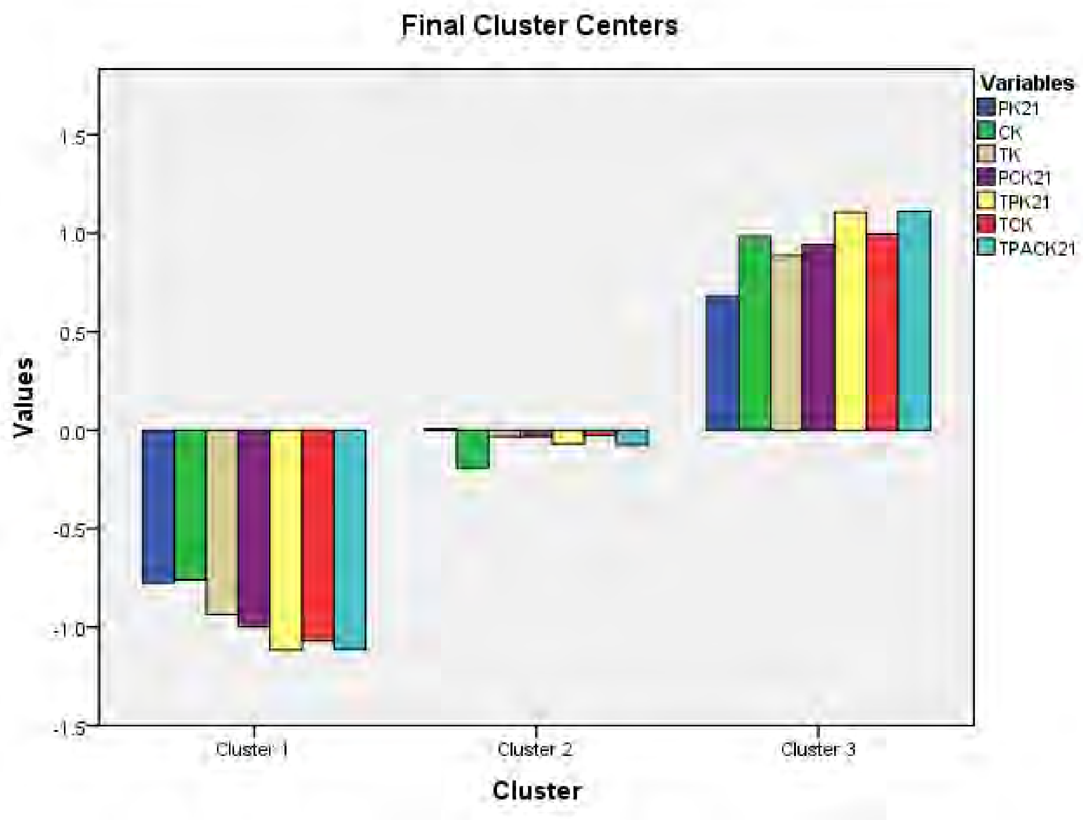

Figure 1. Cluster Centers

The numbers of the members in the three groups ranged between 65 and 116 (Table 2). The clusters were named in accordance with the preservice teachers' strong and weak TPACK-21 areas. The TPACK-21 areas were as follows: "I need more knowledge about the subject" (Cluster 1), "I need a bit more knowledge about the subject" (Cluster 2) and "I have good knowledge about the subject" (Cluster 3).

The preservice teachers in Cluster 1 constituted the group with the lowest scores for the TPACK-21 areas by responding as "I need more knowledge about the subject" (n=65). The strongest areas in Cluster 1 were content knowledge (CK) and pedagogical knowledge (PK21) with the highest scores among the TPACK-21 areas. It was seen that the preservice teachers, especially those in Cluster 1, were quite poor in terms of technological pedagogical knowledge (TPK21). Also, it was revealed that the TPACK-21 areas were quite challenging for the preservice teachers. The findings demonstrated that the preservice teachers still did not have self-confidence in terms of choosing the best methods appropriate to science and mathematics teaching.

In Cluster 2, the response as "I need a bit more knowledge about this subject" (n=116) constituted the biggest group. The Cluster 2 members had the highest scores for pedagogical knowledge (PK21) and technological content knowledge (TCK) among all the TPACK-21 areas. On the other hand, in Cluster 2, the lowest score belonged to content knowledge (CK) among all the TPACK-21 areas. It was seen that the preservice teachers were weak in content knowledge areas necessary to facilitate students' reflecting thinking like group works.

In Cluster 3, the second biggest cluster, the preservice teachers responded as "I have good knowledge about the subject" with respect to all the TPACK-21 areas (n = 73). All the participants in this cluster had self-confidence in all the areas of the TPACK-21 scale. The area with the highest score was the sub-scale of TPACK21, while the lowest score belonged to the area of pedagogical knowledge (PK21). Based on this, it could be stated that the preservice teachers had full self-confidence in terms of using information and communication technologies in the best way while teaching science.

Table 2. Effect size, ANOVA test, Means and Cluster Profiles for the TPACK-21 Scale

	Cluster 1	Cluster 2	Cluster 3	Total			
	n=65	n=116	n=73	n=254	F	p	η^2
PK21	-0,774	0,005	0,681	-0,029	50,703	<0.01	0,288
CK	-0,760	-0,193	0,982	0,010	100,118	<0.01	0,444
TK	-0,936	-0,034	0,887	-0,028	103,682	<0.01	0,452
PCK21	-0,999	-0,033	0,942	-0,030	132,246	<0.01	0,513
TPK21	-1,115	-0,070	1,104	-0,027	259,363	<0.01	0,674
TCK	-1,070	-0,027	0,995	-0,034	173,436	<0.01	0,580
TPACK21	-1,110	-0,077	1,110	-0,025	260,165	<0.01	0,675

Table 3 shows the differences between the cluster groups with respect to their gender, computer use experiences and Internet use frequencies. In the study, the socio-demographic features of the three clusters were compared in terms of the students' gender, computer use experiences and their Internet use frequencies. As can be seen in Table 3, Chi-square test was applied to see whether there were differences between the participants depending on their gender, computer use experiences and Internet use frequencies. The results revealed a statistical difference in the k-means distributions of the participants' gender, computer use experiences and Internet use frequencies in the cluster groups. Most of the women (46,3%) and men (44%) fell into Cluster 2, while there was a balance in Cluster 1 (male 21,3%, female 27,3%). In addition, the preservice teachers' computer use experiences were grouped in the clusters as well. A great majority of the teachers were in Cluster 2 in terms of their computer use experiences (47,3% for 0-1 year, 60% for 2-3 years, 51,6% for 4-5 years and 36,5% for longer than 5 years). In Cluster 3, there were students with the highest self-confidence according to the TPACK-21 scale, and they had the highest levels of computer use experience (46,2%). In addition, the students with the lowest level of computer use experience belonged to Cluster 1, and they had the lowest scores for the TPACK-21 areas (36,5%). As for the clustering done with respect to Internet use frequency, a great majority of the students were grouped in Cluster 2 (68,4% for once a week, 52,9% for 2-3 times a week, 56,7% for 4-5 times a week and 41,9% every day). In Cluster 3, there were students who connected to the Internet regularly every day (32,5%), and in Cluster 1, there were students who connected to the Internet 4-5 times a week (33,3%).

Table 3. Demographic features of the preservice teachers.

Characteristics	Cluster 1 n=65	Cluster 2 n=116	Cluster 3 n=73	χ^2	df	p
Gender				11,935	3	0,008
Male	21,3%(16)	44%(33)	34,6%(26)			
Female	27,3%(49)	46,3%(83)	26,2%(47)			
Toplam	25,5%(65)	45,6%(116)	28,7%(73)			
Computer use experience.				2,042	3	0,564
0-1 year	36,5%(27)	47,3%(35)	16,2%(12)			
2-3 year	22,2%(10)	60%(27)	17,8%(8)			
4-5 year	32,3%(10)	51,6%(16)	16,1%(5)			
5 years and up.	17,3%(18)	36,5%(38)	46,2%(48)			
Frequency of connecting to the Internet.				40,204	9	0,000
1 day per week	15,8%(3)	68,4%(19)	15,8%(3)			
2-3 days a week	17,6%(3)	52,9%(9)	29,4%(5)			
4-5 days a week	33,3%(10)	56,7%(17)	10%(3)			
Every day regularly.	27,7%(49)	41,9%(80)	32,5%(62)			

DISCUSSION AND CONCLUSION

When the results obtained in the study were examined, it was seen that the lowest TPACK-21 score belonged to the response as “I need more knowledge about the subject” and that the lowest scores of the participants in Cluster-1 were in the areas of TPK21, TPACK21 and TCK, respectively (Table 1). According to Ertmer (2005), teachers’ positive attitudes towards ICT integration were important in an effective organization of learning experiences. In technology-aided activities, those with high levels of ICT skills are more successful (Polly,2014). In addition, preservice teachers using ICT in the education process have higher levels of technology knowledge when compared to those who do not make use of ICT skills (Chang, Tsai, & Jang, 2014). Mishra and Koehler (2006) state that key sources of knowledge of ICT integration are the areas of TPK, TCK and TPACK. Teachers should not only learn which technology to integrate and how but also know the importance of practical use of technology. In addition, education faculties should focus on sharing successful examples of specific usages of TPK to strengthen preservice teachers’ beliefs in technology. It is thought that lack of knowledge about student-centered learning approaches and lack of experience in technology have influence on TPACK level. Chai, Chin, Koh, Ling and Tan (2013) reported that lack of technology knowledge has direct influence of TPACK and will decrease individuals' perceptions regarding TPACK.

In Cluster 2, which was grouped with the response as "I need a bit more knowledge about the subject", the area which the students mostly needed knowledge about was content knowledge (CK). In one qualitative study on preservice teachers' attitudes towards learning new ICT technologies, Koh and Diyaharan (2011) found that the students mostly focused on subjects related to TPK and gave less importance to content knowledge.

In Cluster 3, which was grouped with the response as "I have good knowledge about the subject", there were students who had self-confidence in all the areas of the TPACK-21 scale. As can be seen in Table 1, areas with the highest scores were TPACK21, TPK21 and TCK, respectively. The students in this group could be regarded as the generation with self-confidence in terms of using ICT for teaching and learning (Presky, 2001, Tapscott, 2008; Valtonen, Kukkonen, Kontkanen, Mäkitalo-Siegl & Sointu ,2018).

When the clusters were examined in terms of gender, it was seen that 21,3% of the male participants and 27,3% of them female participants were in Cluster 1. Obviously, women need more knowledge than men. In Cluster 2, there was a more balanced distribution. When Cluster 3 was examined, it was seen that 34,6% of the men and 26% of the women had good knowledge about the subject. In the TPACK 21 scale, the men had more self-confidence than the women. In literature, there are a number of studies examining the relationships between the variable of gender and preservice teachers' TPACK levels. In most of these studies, no significant relationship was found between gender and preservice teachers' TPACK efficacies (Çoklar, 2014; Karakaya & Yazıcı, 2017; Ersoy, Yurdakul and Ceylan, 2016), while, as in the present study, the results of some studies revealed significant relationships between gender and the TPACK dimensions (Altun & Akyıldız, 2017; Öz, 2015). Erdoğan and Şahin (2010) and Markauskaite (2006) investigated teachers' attitudes and reported that the male teachers had higher levels of computer use skills than the female teachers. In another study carried out using the TPACK scale with 1.185 Singaporean preservice teachers, Koh, Chai and Tsai (2010) found that the male teachers had more self-confidence in the areas of TK and CK. Daker, Dow and McNamee (2009) and Sanders (2006) pointed out that women were less interested in technology when it was integrated in the teaching and learning process. In addition, Jamieson-Proctor, Finger and Albion (2010) reported that the male teachers had more self-confidence in using instructional technologies when compared to the female teachers. The reason for this difference could be curiosity. In other words, men are more interested in technology and technological devices then women. Therefore, men can use more complex technologies when compared to women. North and Noyes (2002) point out that the spread of computers at schools will provide both men and women with equal opportunities in terms of computer use and thus decrease the differences related to computer use between them.

The results of the present study revealed that a great majority of the preservice teachers using computer for longer than five years (46,2%) were in Cluster 3. Based on this, it could be stated that higher levels of computer use experience increase perceptions regarding TPACK-21. This finding is consistent with those reported by Yağcı (2016), Balçın and Ergün, Karataş (2014) and Kabakçı-Yurdakul (2011).

Another result obtained in this study demonstrated that most of the preservice teachers connecting to the Internet regularly every day (41,9%) were in Cluster 2. In other words, they belonged to the cluster of “I need more knowledge about the subject”. Different from this result, there are several research findings showing that an increase in Internet and computer use leads to a significant difference in terms of efficacy (Demiralay, 2008; Kara, 2011; Kutluca and Ekici, 2010; Sağlam, 2007). For instance, Sağlam (2007) found that the teachers using information technologies more frequently had higher levels of self-efficacies. However, as mentioned before, what is important is not just to use technologies such as the Internet and computer effectively but also to use these technologies together with pedagogy (Kreijns et.al., 2013; Şad and Özhan, 2012). This result might have resulted from the fact that the preservice teachers used the Internet for activities like social media rather than for lessons or other technological issues.

Suggestions

In the present study, the preservice teachers’ efficacy perceptions regarding the TPACK-21 scale were examined, and the findings are thought to contribute to the related literature.

According to the findings obtained in the study, one of the clusters had quite low levels of self-efficacies and knowledge about ICT use in education. The areas that the preservice teachers found most difficult were TPACK21, TPK21 and TCK. Therefore, in order to develop preservice teachers’ efficacy perceptions regarding technology and TPACK-21, technology knowledge should be combined with a pedagogical approach during their education (Chai, Ling Koh, Tsai and Lee Wee Tan, 2011). In this respect:

• Courses covering field and pedagogical knowledge should be given with technology to science and mathematics preservice teachers during their undergraduate education, and their learning process should be supported with technology-based optional courses. This support should be started with freshman students.

• In courses like instructional technologies and material design, technology-based materials could be designed to develop preservice teachers’ TPACK.

• Projects could be executed to develop preservice teachers’ TPACK.

• Preservice teachers could be encouraged to design interactive teaching models to develop their TPACK.

• Preservice teachers with low levels of computer use could be provided with trainings for their TPACK development.

• Preservice teachers could be encouraged to use smart phone applications for their TPACK development. Preservice teachers are supposed to develop their TPACK at all times, and for this purpose, they could be provided with the opportunity to connect to the Internet regardless of place with the help of smart phones and tablets.

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