TPACK Self-Efficacy Perceptions of Science Teachers: A Structural Equation Modeling Study

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Abstract

The purpose of this study is to reveal the relation between Technological Pedagogical Content Knowledge (TPACK) sub-dimensions of science teachers in Turkey. For this purpose, relations between the elements forming the TPACK have been investigated with a model. This research was carried out with 563 science teachers working in 81 schools to represent science teachers in Turkey. The scale developed by Kiray (2016a) to measure TPACK self-efficacy perceptions of teachers and teacher candidates was used as data collection tool in the research. The data obtained in the study were analyzed by structural equation modeling. The direct and positive effects of Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK) and Pedagogical Content Knowledge (PCK) from external variables consisting of binary knowledge domains of the study are seen on TPACK. These variables account for 65% of the change in TPACK. PCK is the variable that affects TPACK the most. According to this finding, PCK has a critical importance in teachers' technology integration. Another important finding in this study is that teachers' CK directly and positively influences TCK and PCK, and this effect is greater than the effect of TK and PK. When considered in the context of the results of this research, a gradual model covering CK and PCK can be proposed instead of a direct technology-based approach to professional development programs developed to increase TPACK self-efficacy of teachers.

Introduction

Despite being regarded as a job of knowing subject matter knowledge until the 1980s, the qualifications expected from teachers today are quite high compared to the past (Kiray, 2016a). Along with Shulman (1986), pedagogical knowledge as well as knowledge of the content in the teaching profession has come to the forefront. The qualities that must be possessed for the teaching profession after Shulman are expressed by the concept of pedagogical content knowledge (Amador, Nobre, & Barros, 2016). With the Mishra and Koehler's (2006) work, the dimension of technology knowledge has

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been added to the features teachers should have. Along with these developments, it is considered that successful science teachers in the 21st century are teachers who can present science knowledge using appropriate teaching strategies and technologies (Lin, Tsai, Chai, & Lee, 2013). For this reason, efforts to equip science teaching and learning environments with up-to-date teaching technologies are continuing in many countries, especially in the United States (USA), UK and Germany (Pamuk, Çakır, Ergun, Yılmaz, & Ayas, 2013). Nowadays, notebook computers, interactive phones, mobile technologies, video editing systems, electronic and interactive software, and internet based learning systems are integrated into science classes as the first priority digital technologies (Aktürk, Mihçi, & Çelik, 2015). In the next decade it is inevitable that new names are added to this list or that this list is updated from the beginning. With new technologies, science learning has moved beyond school walls, distance education, e-learning, mobile learning, interactive classroom practices have begun to increase. It has become a top priority for science teachers to integrate content knowledge and pedagogy knowledge in rapidly changing technologies to increase quality in science teaching in the 21st century, as new teaching technology emerges and flourishes each passing day. However, as a result of the researches, it was realized that technology would not contribute independently to pedagogical knowledge and content knowledge and it started to focus on the integration of technology into the learning-teaching process (Gill & Dalgarno, 2017; Graham et al., 2009; Kumar, 2017). This leads to the concept of technological pedagogical content knowledge.

Theoretical Framework

In Koehler and Mishra's (2009) studies, technological knowledge, pedagogical knowledge, and content knowledge are shown as three sets of intersecting venn diagrams. Koehler and Mishra (2009) gave the TPACK name to the intersection of these three sets. Today, however, TPACK is conceptualized as integrating pedagogy and technology knowledge onto special content knowledge. When the content knowledge is taken as science in the diagrams of Koehler and Mishra, the TPACK concept becomes special to science (Lin et al., 2013). In the study of TPACK adaption to science education, Kiray (2016a) explained the 7 dimensions that emerged in Koehler and Mishra's venn scheme as follows.
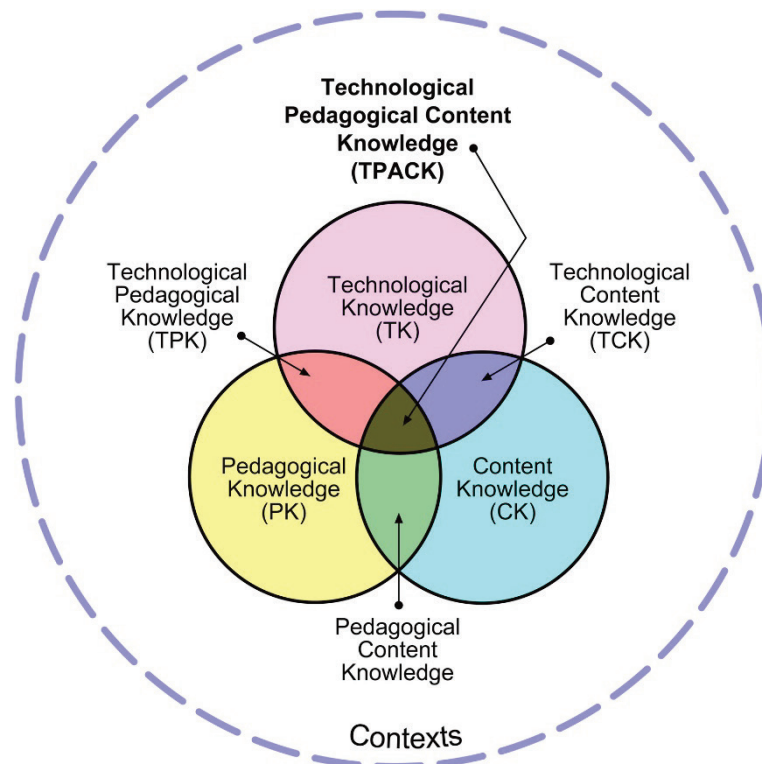

Figure 1. The TPACK Framework and Its Knowledge Components (Koehler & Mishra, 2009)

1- Technological Knowledge (TK): General knowledge about technology. It incorporates as much space as traditional technologies (such as laboratory materials, etc.) as computer and internet based technologies (such as blogs, mobile devices, etc.).

2- Pedagogical Knowledge (PK): General knowledge about learning and teaching ways. Teaching-learning encompasses a wide range of strategies, approaches, techniques, methods, models and theories, measurement and assessment approaches, classroom management, and lesson planning by accounting for individual differences between learners.

3- Content Knowledge (CK): It is knowledge about the subject matter. It is a wide domain that requires to know about sufficient knowledge of the subjects of physics, chemistry, biology, astronomy and earth sciences that constitute the science lesson, the concepts, principles, generalizations, theories and laws that are planned to be taught within the scope of science lessons, the content knowledge regarding the interaction among science, technology, society and environment, and the content knowledge regarding the scientific process skills and the nature of science.

4- Pedagogical Content Knowledge (PCK): It is the pedagogical knowledge that must be possessed for the teaching of a particular subject matter. It aims to integrate pedagogy knowledge with subject matter knowledge.

5- Technological Content Knowledge (TCK): It is the technological knowledge that must be possessed for the teaching of a particular subject matter. It aims to integrate subject matter knowledge with technology knowledge.

6- Technological Pedagogical Knowledge (TPK): General knowledge about how technology use affects teaching and learning. It aims to integrate pedagogy knowledge with technology knowledge.

7- Technological Pedagogical Content Knowledge (TPACK): Knowledge about the integration of a specific subject matter with technological and pedagogical knowledge. It is associated with PCK, TPK and TCK.

In the theoretical model of TPACK, it is stated that the knowledge of CK, PK and TK should be considered in an interactive manner, not independent of each other (Mishra & Koehler, 2008). For example, a teacher who wants to use an inquiry-based teaching strategy on 'cells unit' does not have to have only content knowledge about the subject matter or only teaching method as pedagogical knowledge or only technology knowledge (e.g., simulations). The teacher should be able to determine the technological tools that can be used in the teaching of the subject matter, understand how the determined technologies can affect inquiry based learning processes of the students, and have knowledge for how and when they can integrate technological tools into the teaching process by considering the students' preliminary knowledge about the cells unit, the concepts they may have difficulty in understanding, and misconceptions they may bring with them. (Canbazoğlu Bilici & Baran, 2015).

Literature Review

Theoretically, although TPACK has seven sub-dimensions, it is generally regarded as effective technology integration, and it is seen that research on technology part is gaining more weight (Kabakçı Yurdakul et al., 2012). Two different trends are seen when TPACK's technology dimension is in the forefront. First of these is the studies that take into account only the technology-related dimensions and exclude the CK, PK, and PCK dimensions that do not consist technology dimension (Graham et al., 2009). The second is the studies that observe the change in TPACK self-efficacy of students or teachers, focusing only on the dimension of technology (Guzey & Roehrig, 2009; Jang, 2010).

With the Koehler and Mishra's (2006) studies, it has been understood that integration of educational technologies into curricula is an important step for effective learning. This makes it a necessity for teachers to use different technological tools and to improve their technology literacy (Jang & Tsai, 2013). Nevertheless, it is observed that the teachers do not feel ready to use the technology in

educational environments (Çelik, Şahin, & Aktürk, 2014). Jang (2010) conducted a science-focused research using interactive whiteboard with science teachers. These teachers, who have just started using the interactive whiteboard, have chosen the topic of heat and temperature as their subject matter knowledge to apply for their training. The teachers in the study have shown that their level of PCK confidence is good in this subject matter. Teachers have added technology dimension with interactive board to their PCK knowledge that was sufficient. At the end of the application, they stated that the use of interactive whiteboards by teachers makes it very easy for them to use their knowledge of the content, and that they are beginning to teach many topics that they have difficulty teaching before using an interactive whiteboard. The introduction of technology has greatly contributed to the teaching of science teachers with a good level of PCK self-efficacy. As a result, the use of interactive whiteboard technology by teachers with a high PCK level has increased the TPACK self-confidence of science teachers.

Guzey and Roehrig (2009) have implemented a program for middle school science teachers named Technology Enhanced Communities. This program aims to let teachers to integrate various educational technologies with pedagogy and science knowledge in an inquiry based learning environment. The training that teachers received regarding use of technology in teaching science has also increased their use of pedagogical knowledge. This study has shown that the self-efficacy of teachers regarding their pedagogical knowledge increases as technology knowledge increases. Graham et al. (2009), in their study, has made an application named SciencePlus, which aims to teach science teachers science supported with digital technology. At the end of the application, the self-confidence of the teachers were seen to be ranked from highest to lowest in terms of TK, TPK, TPACK and TCK. This research shows that teachers integrate digital technologies most difficultly into the content knowledge dimension among TPACK's three basic sub-dimensions. While teachers did not find it difficult to integrate technology with pedagogical knowledge when they were educated, it revealed that their self-confidence in integrating with content knowledge was less. In a longitudinal study, in-service professional development workshops consisting of TPACK-based activities have positively affected teachers' self-efficacy of TCK, TPK, context knowledge, TPACK (Canbazoğlu Bilici & Baran, 2015). In the study that Kafyulilo, Fisser, and Voogt (2014) conducted with science teachers, the greatest increase in teachers' self-efficacy after TPACK-based in-service professional development workshops was in TCK, TPACK, TPK and TK dimensions respectively. In another study conducted with 665 candidate science teachers at seven different universities in Turkey, a structural equation model for the TPACK self-efficacy of participants was developed. In the developed model, TK and PK had no direct effect on TPACK but indirect effect via PCK (Günbatar, Damar, & Boz, 2017). In the relevant literature, most researchers have suggested that CK is prerequisite for PCK (Kleickmann et al., 2013). For example, Canbazoğlu, Demirelli, and Kavak (2010), in the study of the granular structure of matter unit, reported that the subject matter knowledge of teacher candidates influenced the teaching methods and techniques that they used. They found that the candidates used the method of straight lecturing in places where the subject matter knowledge was lacking. In the same study, it was revealed that teacher candidates had difficulty in selecting appropriate expressions while teaching the subjects that they did not have complete mastery, and that they had misconceptions in these matters. This suggests that the concept of PCK introduced by Shulman (1986) changes depending on the specific subject matter. For this reason, teachers need to develop pedagogical content knowledge that is specific to each subject matter (Akerson, Carter, Rogers, & Pongsanon, 2018; Aydoğan Yenmez, Erbaş, Alacacı, Çakıroğlu, & Çetinkaya, 2017; Shulman, 1986; Tekkaya & Kılıç, 2012). Baran and Canbazoğlu Bilici (2015), in their literature study on TPACK, stated that all the theoretical studies made on TPACK are US-based (Chai, Koh, & Tsai, 2013) and new theoretical studies are needed for a better understanding of TPACK knowledge structure in Turkey.

Significance of the Study

Although there are TPACK studies on science education in the relevant literature, these are mainly experimental studies that examine the effects of teaching of a unit or topic on TPACK self-efficacy of teachers or teacher candidates, or the limited number of qualitative research that includes opinions of teacher/teacher candidates on TPACK self-efficacy. This study differs from other studies

because it is a screening study that will reveal the relationship between TPACK self-efficacy of science teachers all around Turkey and sub-dimensions of TPACK. It is expected that the relationships between the sub-dimensions of TPACK and the determination of the types of knowledge that are effective in TPACK will shape the training and implementation of the teacher professional development programs that intend to enhance TPAB self-efficacy of teachers. Furthermore, it is emphasized that the relationship between the knowledge constituting the TPACK theoretical framework in the literature is still unclear (Chai, Ng, Li, Hong, & Koh, 2013) and that the TPACK levels of teachers vary based on their branches (Kula, 2015). The results of this research are important because the relationship between the TPACK self-efficacy of science teachers may differ from other branches. The purpose of this study is to reveal the relation between TPACK sub-dimensions of science teachers in Turkey. For this purpose, the relations between the constituents of TPACK will be examined by a structural equation modeling. The following questions will be answered in this study:

1- Which variables affect science teachers' technological content knowledge and how much do these variables explain technological content knowledge?

2- Which variables affect science teachers' technological pedagogical knowledge and how much do these variables explain technological pedagogical knowledge?

3- Which variables affect science teachers' pedagogical content knowledge and how much do these variables explain pedagogical content knowledge?

4- Which variables affect science teachers' technological pedagogical content knowledge and how much do these variables explain technological pedagogical content knowledge?

Method

Research Design

Relational scanning model was used in the study. With this model, it is aimed to determine the relationship between two or more variables and to obtain clues about cause and effect (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2008). The variables of this study consist of CK, PK, TK, TCK, PCK, TPK and TPACK factors that are sub-dimensions of TPACK theoretical structure.

Universe and Sample

In this research, science teachers who were working in Turkey during 2016-2017 academic year were taken as universe. From this universe, stratified samples were formed by determining the number of science teachers in the provinces. This research was carried out with 563 science teachers working in 81 schools to represent science teachers in Turkey. In the study, science teachers working in all provinces of Turkey were first identified by the stratified sampling technique (36,546 teachers as of 2016-2017 academic year). How many science teachers from which provinces will be involved in the research were determined through dividing the number of science teachers working in a province by the number of all science teachers in Turkey (ratio coefficient: 0.015). For example, 16 of the 1,089 teachers working in Adana and 33 of the 2,219 teachers working in Ankara participated in the survey. 296 of the teachers participating in the survey were male, 267 were females. 497 of the teachers were graduated from faculty of education, 12 from education institute, 46 from faculty of science and literature, and 8 from faculty of engineering. The average age of the teachers is 32.63.

Data Collection Tools

The scale developed by Kiray (2016a) to measure TPACK self-efficacy perceptions of teacher and teacher candidates was used as a data collection tool in the research (Appendix-A). The scale consists of 55 items and seven sub-dimensions. The developed scale is Likert type with 5 options range from "1-I do not know" to "5-Very good level of knowledge". Reliability coefficients and related sub-dimensions are as follows: CK (0.866), PK (0.902), TK (0.875), TCK (0.916), PCK (0.792), TPK (0.922), and TPACK (0.924). The reliability coefficient for the overall scale is 0.969. Confirmatory factor analysis was performed in the scale development process, and the factor loadings of the scale items ranged from 0.37 to 0.83. Test-retest reliability of the scale is 0.82. In this study, the reliability coefficients of the data on

the subscales of the scale were found to be CK (0.883), PK (0.892), TK (0.905), TCK (0.896), PCK (0,798), TPK (0.874) and TPACK (0.829). The Cronbach alpha reliability coefficient for the overall scale was 0.862. When the expected reliability coefficient for the data tools that can be used in the research is 0,70 (Anastasi, 1982; Tezbaşaran, 1997), it is seen that the reliability level towards the TPACK scale is high.

The TPACK self-efficacy scale used in this study also differs from other TPACK scales in the way of development. The scale was developed in three stages. The first stage forms the sub-dimensions TK, CK, PK. The second stage emerged when these three sub-dimensions were integrated with each other. By combining the TK and CK sub-dimension items, the TCK dimension of the second phase, by combining TK and PK sub-dimension items, the TPK dimension of the second phase, and by combining PK and CK sub-dimension items PCK dimension of the second phase have been formed, which means that the second stage is built on the first stage. The third stage is the integration of the PCK, TPK and TCK sub-dimensions in the second stage. Because of this feature, this study differs from other TPACK studies. In this study, the effect of TPACK self-efficacy on other sub-dimensions is foreground.

Data Analyses

Structural equation modeling was used in the analysis of data in this study. Structural equation modeling is a statistical approach to test causal and reciprocal relationships between observed and latent variables to test a theoretical model (Schumacker & Lomax, 2004). In this study, the predictive relations between TC, PK, CK, PCK, TCK, TPK, TPACK of science teachers were analyzed by Maximum Likelihood technique using AMOS 19 Program according to Structural Equation Model.

Data Collection Process

The data in the study were collected with the support of the Ministry of National Education. The scale used in the research was transferred to the electronic environment by the ministry and the teachers were asked to fill the scale online. Each teacher individually filled the scale in electronic form. With the control questions placed in the scale, the answers given by the teachers were checked. As a result of these control questions, the data for the teachers who were found not to answer the scale appropriately were removed from the study. Instead of these teachers, other teachers from the same cities filled electronic form, so that the data obtained from 563 science teachers were included in the study so as to preserve the number of samples. As a result of the relevant control questions, the data for 37 teachers (22 female, 15 male) determined not to adequately respond to the scale were withdrawn from the study. Instead of these teachers, other teachers from the same provinces were included in the study and the data from 563 science teachers were included in the survey so as to preserve the number of samples.

Results

Structural equation analysis was applied to determine the relationships between the variables of the study, TK, PK, CK, PCK, TCK, TPK and TPACK. The structural equation model tested in the study includes six exogenous variables (TK, PK, CK, PCK, TCK, TPK) and an endogenous variable (TPACK). The fit indices of the structural equation model in the study are shown in Table 1.

Table 1. Fit Indices for TPACK Model

Measure	Good Fit	Acceptable Fit	Fit Indices for TPACK Model
($\chi2$/sd)	≤ 3	≤ 4-5	3,557
RMSEA	≤ 0,05	0,06-0,08	0,067
NFI	≥ 0,95	0,94-0,90	0,973
CFI	≥ 0,97	≥ 0,95	0,992
GFI	≥ 0,90	0,89-0,85	0,954
AGFI	≥ 0,90	0,89-0,85	0,924
TLI	≥ 0,95	0,94-0,90	0,986
IFI	≥ 0,95	0,94-0,90	0,992

According to Şimşek (2007), a small value of χ2 goodness of fit is considered as a sign of the model being consistent with the obtained data, and this value is expected to be smaller than 3. In most cases this criterion is not met, so the value obtained by dividing χ2 by the degree of freedom (df) is checked. If χ2 / (sd) is less than or equal to 3, the model is well adapted; and if the value is less than 5 or equal to 4, the model shows the acceptable fit (Meydan & Şeşen, 2011). Another commonly used fit index to test the fit of structural equation models is the Root Mean Square Error of Approximation (RMSEA). According to Sümer (2000), perfect fit of RMSEA is less than or equal to 0.05; and values of up to 0.08 also indicate acceptable fit. The χ2 / (sd) and RMSEA values of the TPACK model generated in this study are at the acceptable level of fit. When Table 1 is examined, other indices of the TPACK model show that the model has good fit values (Hu & Bentler, 1999; Jöreskog & Sörbom, 1984; Tanaka & Huba, 1985). As shown in Table 1, the TPACK model has acceptable fit indices (Hu & Bentler, 1999; Tanaka & Huba, 1985; Jöreskog & Sörbom, 1984). The research model is shown in Figure 2 and only statistically significant paths are included in the model.
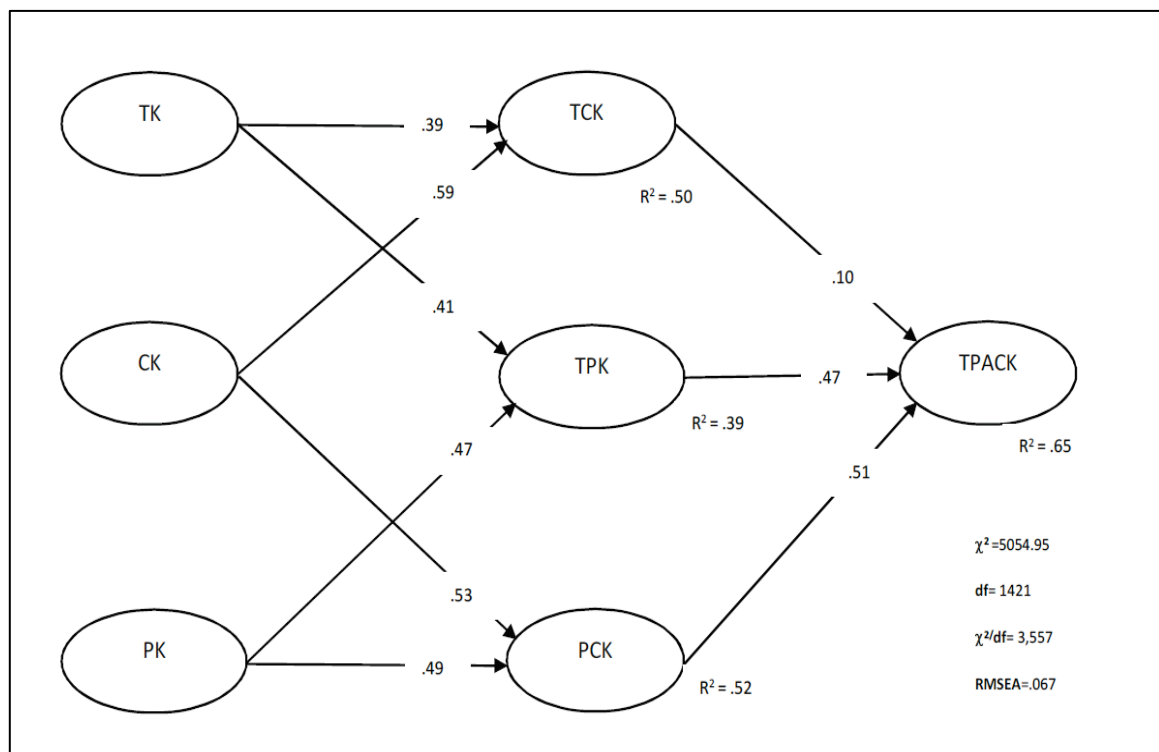

Figure 2. TPACK Model

In Figure 2, TK (β = 0.39) and CK (β = 0.59) positively and directly affect TCK and explain 50% of TCK variation. In addition, TPK is explained by TK (β = 0,41) and PK (β = 0,47) by 39%. Likewise, CK (β = 0.53) and PK (β = 0.49) positively and directly affect PCK and explain 52% of the change in PCK. Direct and positive effects of TCK (β = 0,10), TPK (β = 0,47) and PCK (β = 0,51) on TPACK are observed, which are other external variables consisting of the study's binary knowledge domains. These variables account for 65% of the change in TPACK. PCK is the variable that affects TPACK the most. According to this finding, PCK has a critical importance in teachers' technology integration. TPK is the second variable that has the greatest effect on TPACK self-efficacy perceptions of teachers after PCK. These two findings reveal that teachers' ability to integrate pedagogical knowledge with content knowledge and technological knowledge has an impact on TPACK self-efficacy. TCK (β = 0,10) has less effect on TPACK self-efficacy perceptions compared to the other two dimensions.

Discussion

The purpose of this study is to determine the relationships between TPACK self-efficacy levels and TPACK sub-dimensions of science teachers. For this purpose, data were collected from 563 science teachers working in different cities of Turkey. As a result of the analysis of the obtained data, a model explaining TPACK at 65% level was created. In the other studies that investigated the relationships between TPACK sub-dimensions, TPACK's level of explanation is between 54% and 76% (Günbatar et al., 2017; Çelik et al., 2014; Övez & Akyüz, 2013).

In this model, TK and CK are directly and positively influencing TCK. Accordingly, the ability to choose the most appropriate technology for the subject taught in science classes by teachers who see themselves adequately in the dimensions of technological knowledge and science content knowledge is also increasing. The findings of this study, the positive and direct effect of TK and CK on TCK shows that these two knowledge types enhance the teachers' TCK at the same time. However, investigations point out that independently having sufficient knowledge in these two domains are not sufficient for TCK, and that the integration of these two areas should be specifically taught (Cengiz, 2013). Graham et al. (2009) found that self-efficacy of teachers in integrating technological knowledge into the content knowledge is less than integration of pedagogical knowledge. The fact that the effect of CK on TCK is higher than that of TK in this research model shows that science teachers' content knowledge is more effective than technological knowledge in the integration of these two sub-dimensions. In some studies in the literature, teachers who see themselves adequate in terms of their content knowledge show that they are more successful in choosing appropriate technology for the subject they teach (Akarsu & Güven, 2014; Chai, Koh, & Tsai, 2013; Kafyulilo, Fisser, & Voogt, 2014).

PK and TK directly and positively affect teachers' TPK self-efficacy perceptions. According to this finding, the increase in PK and TK of science teachers also cause an increase in teachers' knowledge of using technology with pedagogical purpose in teaching process. Guzey and Roehrig (2009) in their studies stated that TK and PK affect each other positively. At the end of Graham et al. (2009)'s technology-focused practices, the increase in TPK self-efficacy of teachers became more than TPACK's other technology-related dimensions. The fact that the effect of PK on TPK is higher than that of TK in this research suggests that technology integration process should be based on pedagogy. In recent years, it has been observed that technology integration models tend to shift from technology-focused models to pedagogical-focused models. In other words, while technology-focused models aim to have teachers acquire knowledge and skills for the use of technology, pedagogy-focused models are models that aim to link teachers' knowledge of technology utilization with pedagogical knowledge throughout their teaching (Baran & Uygun, 2016; Yurdakul, 2011). In another research, teachers' TPACK structures were investigated after in-service trainings regarding information and communication technologies. In line with the findings of this study, it has been found that the strongest correlation between TPACK sub-dimensions of teachers is between TP and TPK (Chai et al., 2011). Similarly, in another study in which TPACKs of science teachers are modeled, TP and PK have a direct and positive effect on TPK, whereas PK has a greater effect than TK (Günbatar et al., 2017).

PK and CK self-efficacy of science teachers have direct and positive effect on their PCK self-efficacy. As stated by Shulman (1986), teaching is a profession that requires the use of content knowledge and pedagogical knowledge together. For this reason, the integration of these two fields is a necessary condition for the teaching profession according to Shulman (1986). This research also shows that the PCK dimension indicated by Shulman (1986) for teaching is directly related to teachers' self-efficacy in pedagogical and content knowledge. For this reason, the development of the knowledge of science teachers in these two areas and the integration of these two areas must be recognized for teaching profession (LeBlanc, Cavlazoglu, Scogin, & Stuessy, 2017). In some studies conducted in the literature, it is stated that teachers' lack of theoretical knowledge regarding the subject matter they teach causes students' misconceptions, different representations of the subject matter, and the choice of inappropriate metaphors (Tondeur, Scherer, Siddiq, & Baran, 2017). In their research, Canbazoğlu et al. (2010) pointed out that teachers' lack of conceptual knowledge about the area that they teach prevents

them from choosing different ways of teaching while teaching the concepts to students. Therefore, competence in content knowledge directly affects teachers' PCKs. Teachers who see themselves adequate in the context of what they teach do not have any concerns about feedback to students (Koh, Chai, & Tay, 2014; Rosenberg & Koehler, 2015).

In different researches made in the literature, it has been found that TPK, TCK and PCK are directly and positively affected by the types of knowledge they are formed (Chai, Koh, Tsai, & Tan, 2011; Çelik et al., 2014; Övez & Akyüz, 2013; Savaş, 2011). Hechter, Phyfe, and Vermette (2012) stated that TK, PK and CK of teachers should be increased as the first step of technology integration. As the relevant three basic types of knowledge directly impact TPK, TCK and PCK, the lack of these types of knowledge will prevent effective technology integration. Although knowledge and skills in the core areas (TK, PK and CK) are essential in order to constitute knowledge and experience necessary for effective technology integration, only these types of knowledge are not enough to enable the integration of technology (Angeli & Valanides, 2009; Pamuk, Ülken, & Dilek, 2012). In addition to being knowledgeable in the main domains, teachers should be able to use this knowledge in relation to other domains (Pamuk et al., 2012).

According to another finding reached in the research, the TPK, TCK and PCK of science teachers directly and positively affect their TPACK. Harris and Hofer (2011) found a finding parallel to the findings of this study. Harris and Hofer (2011), in their studies indicating the importance of activity-based TPACK training, reached the conclusion that TPK, TCK and PCK competencies have increased in direct proportion along with TPACK competencies. Therefore, in the pre-service and in-service trainings regarding the integration of technology, teachers should focus more on how to use a particular technological device in the subject matter context that will be taught, rather than on how to use it. Cengiz (2013) observed that teachers are challenged in their classroom practice because in-service trainings regarding technology is based on theoretical knowledge and that the technological tools are taught independently of the subject area. Researchers who emphasize the importance of the development of teachers' TPK, TCK and PCK for effective technology integration emphasize that training programs should be applied where technology, teaching methods and subject areas interact (Canbazoğlu Bilici & Baran, 2015; Harris & Hofer, 2011; Higgins & Spitulnik, 2008). Because providing classroom equipment, facilitating teachers' access to technology, and increasing their attitude towards technology will not guarantee the integration of technology in the teaching process (Perkmen & Tezci, 2011). In the related literature, it is seen that TPK, TCK, and PCK of teachers directly and positively influence their TPACK in accordance with the findings of this research (Cox & Graham, 2009; Günbatar et al., 2017; Hechter et al., 2012; Lin et al., 2013; Young, Young, & Hamilton, 2013).

In this study, it was found that the effect of content knowledge on TCK, which is the sub-dimension of TPACK, was more than the technological knowledge, and similarly the effect of content knowledge (CK) on PCK dimension was more than pedagogy (PK) dimension. Teachers who rely on science knowledge seem to have more confidence in integrating technology and pedagogy into this content knowledge. This reveals that the content knowledge, which remains in the shadow of the pedagogical and technological competencies in the education field, must be reviewed. The findings of this research show that teachers with sufficient content knowledge have more self-confidence to integrate both technological knowledge and pedagogical knowledge into this content knowledge. Some studies in the literature show that reverse of this is not possible. Graham et al. (2009), at the end of a technology-focused program called science plus, revealed that self-confidence of teachers in integrating technology into content knowledge (TCK) was at the lowest level compared to other technology dimensions in the TPACK model (TK, TPK, TPACK). In other words, when technology-focused education is given instead of education by integrating technology into the content knowledge and teachers are expected to increase their self-efficacy on content knowledge, negative result is obtained. Similarly, Ansyari (2012), at the end of the three-week TPACK application, stated that while teachers' self-efficacy on content knowledge (CK) did not change, there was an increase in other dimensions of TPACK. Kleickmann et al. (2013) have reached the conclusion that the increase of CK in the research

they conducted has also increased the PCK. In this study, a similar relationship between CK and PCK is also seen between CK and TCK.

Another important finding from the model in this study is that the PCK is the kind of knowledge that affects science teachers' TPACKs the most. According to this result, it can be said that the pedagogical content knowledge is an integral component of the technology integration in education. In other words, a teacher who does not know how to best teach the concepts of science will not be able to integrate technology into the teaching process at an adequate level, no matter how much technology knowledge she has. Because a teacher's pedagogical knowledge (PCK) for the subject area will also guide the technology that he will use in his class (Beschorner & Kruse, 2016; Şahin, Çelik, Oğuz Aktürk, & Aydın, 2013). PCK is also a critical factor in the studies for technology integration. In the study of Çelik et al. (2014), it is seen that PCK is one of the variables affecting TPACK of teacher candidates. In Jang's (2010) study, it was found that the teachers with high PCK level is also very successful in integrating technology into the lessons. So and Kim (2009) argue that the lack of teacher candidates' PCK in their work prevents them from integrating technology into the subject areas they will teach. Similarly, in a study on the modeling of TPACKs of science teacher candidates, PCK was found to be the variable that affects their TPACK the most (Günbatar et al., 2017).

Conclusion and Suggestions

In the studies in the literature, it is seen that the generally technology dimension of TPACK is foregrounded. Much of the TPACK-related work deals only with technology-related dimensions. However, it is seen that the PCK dimension has the most effect on the TPACK self-efficacy of science teachers in this study. Shulman's PCK concept emerges as the most important sub-dimension to explain the TPACK self-efficacy.

When the findings of this research are compared with the studies in the literature, it is understood that integrating the PCK on CK and then integrating the technology on PCK will have more effective results in terms of TPACK self-efficacy perceptions. In other words, with appropriate pedagogy training for teachers who are sufficient in terms of CK, it is possible to increase the PCK self-efficacy and with appropriate technology training for teachers who are sufficient in terms of PCK, it is possible to increase the TPACK self-efficacy of teachers. When considered in the context of the results of this research, a graduated model, including CK and PCK, can be proposed instead of a technology-focused approach to the in-service teacher trainings for effective technology integration. For example, in professional development workshops, science teachers can be trained to teach models in detail, which can be found in the conceptual frame of the atom and exist in the minds of students (Kiray, 2016b). The teacher who is master of the content knowledge can then make sample applications about which methods and techniques (drama, role playing etc.) can be used in teaching. The teacher who has sufficient knowledge in terms of PCK can make an application about how to make the subject more concrete and understandable by using appropriate technologies (simulation, animation, video, etc.). Likewise, in applied lessons, it is suggested that science teacher candidates can carry out practices in which PCK will be added on top of CK and technology on top of PCK, so that their TPACK self-efficacies can be increased. In the following researches, it is important that the teachers' TPACK self-efficacy is investigated by in-depth interviews and long-term observations with reference to the results of this research. In this study, participants were composed of science teachers in different provinces of Turkey. Therefore, the findings of this study are limited to science teachers in Turkey. For this reason it may be advisable to investigate teachers' TPACK self-efficacy in different branches or in different cultures. At the same time, it may be advisable to investigate TPACK self-efficacy of teacher candidates.

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Appendix 1. TPACK-Science Self Efficacy Scale

1. How to use the materials used in the teaching-learning process in a science laboratory (activity/experiment materials like microscope, radiometer, dynamometer, thermometer)

2. How to use the electronics-based teaching technologies (computer, projection, television, camera, video, etc.)

3. How to use the essential software programs (Word, Excel, and PowerPoint etc.)

4. How to use interactive technological learning tools (interactive whiteboard/LCD panel, tablet, digital course book, etc.)

5. How to use mobile learning tools (tablet, mobile phone etc.) with internet support

6. How to use multimedia (video clips, animation, simulation, virtual lab, etc.)

7. How to create distance learning environments through social networks that provide audio and visual communication (skype, messenger etc.)

8. How to use digital software (java simulation, inspiration, graphic calculator etc.)

9. How to create a social environment on the internet (discussion boards, wikis, web blogs, electronic document sharing)

10. How to develop daily, yearly and unit plans

11. How to use classical (multiple choice, fill-in the blanks, etc.) and alternative/complementary (Portfolio, rubric etc.) measurement and assessment tools for evaluating student performance

12. How to use different teaching strategies (verbal learning, discovery learning, inquiry-based learning, etc.)

13. How to use different teaching methods (Problem-based learning, Project based learning etc.)

14. How to use different teaching techniques (Brainstorming, Six thinking hats, Analogy, Metaphor, Station, drama, snowball, exhibition, panel, forum, etc.)

15. How to use different teaching-learning approaches, and theories (behaviorist, constructivist, multiple intelligence, etc.)

16. How to teach based on different teaching-learning models (5E, 7E learning models etc.)

17. How to plan lessons by taking the individual differences of the students into consideration

18. Classroom management according to different teaching-learning approaches

19. Adequate content knowledge of physics for my profession

20. Adequate content knowledge of chemistry for my profession

21. Adequate content knowledge of biology for my profession

22. Adequate content knowledge of astronomy for my profession

23. Adequate content knowledge of earth science for my profession

24. Content knowledge regarding the interaction of science-technology-society-environment

25. Content knowledge regarding scientific process skills and the nature of science

26. The common scientific misconceptions

27. Content knowledge regarding the concepts, principles, generalizations, theories and laws of Science

28. How to use the technologies that are suitable to different teaching theories, approaches and mode

29. How to use the technologies that are suitable to different teaching strategies, methods and techniques

30. How to utilize technology according to students' individual differences

31. How to utilize technology while carrying out measurement and assessment (electronic portfolio, online test, online rubric etc.)

32. How to decide whether a new technology is suitable for teaching

33. Classroom management while using different teaching technologies

34. How to use technology in a way that affects learning positively

35. How to decide on the appropriate teaching technologies for different learning areas of Science (physics, chemistry, biology, astronomy …)

36. How to utilize technology in a way that enables to learn the concepts of science better

37. How to choose the technologies that will enable to learn Science content knowledge more easily

38. How to decide on the technologies that will enable to learn Science content knowledge in a meaningful way

39. How to decide on the appropriate technologies depending on the characteristics of Science content knowledge (simulation for teaching electrics, using models for teaching DNA, etc.)

40. How to integrate my knowledge about the learning areas of science with appropriate teaching technologies

41. How to utilize technology at the correct place and inadequate time while teaching science content

42. How to prepare lesson plans in accordance with the outcomes stated in science curriculum

43. How to choose the theories, approaches, models, strategies, methods and techniques that are appropriate to the outcomes stated in science curriculum

44. How to evaluate by using the assessment tools that are appropriate to the outcomes stated in science curriculum

45. How to design in-class and out-of-class activities that are appropriate to the outcomes stated in science curriculum

46. How to prepare science content by taking the students' individual differences into consideration

47. How I can teach the concepts of science in a more comprehensible and thorough way

48. How to resolve common misconceptions in science

49. How to integrate the outcomes of science with appropriate strategies, methods, techniques, and technologies

50. How to choose the appropriate strategies, methods, techniques and technologies that will enable to learn Science content better

51. How to decide on the appropriate pedagogical and technological applications for the learning areas of science (physics, chemistry, biology, astronomy, earth science, etc.)

52. How to integrate my content knowledge with my pedagogical and technological knowledge in a way that will increase the value of students' learning

53. How to adapt the emerging strategies, methods, techniques, models, and technologies to the outcomes of science

54. How to guide my colleagues in integrating the outcomes of science with appropriate technologies and pedagogies

55. How to restructure my content knowledge by using my technological and pedagogical knowledge in a way different from the presentation style of knowledge in the course book