TPACK levels of physics and science teacher candidates: Problems and possible solutions

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Contents

Abstract

This research examined whether the technological pedagogical content knowledge (TPACK) of physics and science teachers is at a sufficient level and whether the TPACK level affected the academic achievements of the students. In the research, a mixed method was used quantitatively and qualitatively. In the quantitative part of the research, Provus' assessment model was exploited in order to determine whether the TPACK levels of the teacher candidates were sufficient. On the other hand, in the qualitative dimensions of the research, we tried to determine whether there was a significant relationship between the academic achievements and TPACK levels of physics and science teacher candidates, and whether it predicted academic achievement in a significant manner. As a result of the data analyses, significant results were found in favour of physics teacher candidates in terms of their academic achievement and TPACK attitudes. Furthermore, it was also found that TPACK scores predicted the academic achievement scores of the teacher candidates positively. However, the TPACK levels of the teacher candidates in both departments were found to be insufficient, according to Provus' assessment model. In the qualitative dimension of the research, an in-depth interview method was utilized in order to determine to what extent the TPACK levels of the teacher candidates were affected, where the differences between the two departments originated, and from what the insufficiencies in the TPACK levels resulted. In-depth interviews were conducted with a total of 10 teacher candidates from both departments. The data which was obtained from the interviews cast substantial light on the findings of the research.

Keywords: computer based learning, laboratory based learning, science education, technological pedagogical and content knowledge.

Introduction

Together with the development of information technologies, many transformation processes in the education and instruction field have also begun. Information technologies not only provide many opportunities for learners but also lead to a significant change in the methods and beliefs used by teachers. However, there are complicated problems in the integration of technology with education and instruction, despite such change and effectiveness in these fields. Therefore, we should understand the reasons underlying the incentives which enable teachers to integrate technology in their own fields. Digital technology leads to a significant change in terms of instruction in the education field, as in all fields in which human beings work (Harris, Mishra, & Koehler, 2009; Koehler, Mishra, & Yahya, 2007). However, it is believed by many scholars that education cannot change its vision along with technology because there are some problems in relation to how technology should be inter-used with education and instruction (Schmidt, Baran Sahin, Thompson, & Seymour, 2008). Studies which were conducted on the integration of technology have highlighted that technological knowledge should be considered alongside content knowledge and pedagogy knowledge. The technological pedagogical content knowledge (TPACK) theory was presented in line with this purpose.

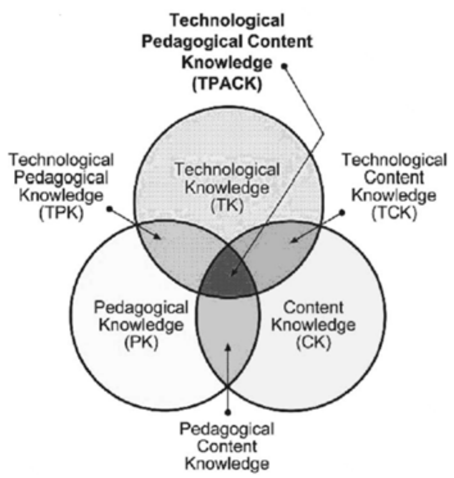

Figure 1. Scheme showing TPACK structure

TPACK is a theory which presents the relationships between the technological, pedagogical, and content (field) knowledge of teachers and students. Mishra & Kohler (2006) define TPACK theory as the interaction and communication among these three types of knowledge. The draft which is used for describing TPACK theory is illustrated in Figure 1. In this draft, there are three interconnected components: technological, pedagogical, and content (field) knowledge. Explanations regarding these are given respectively, as follows.

Technological knowledge (TK) refers to the knowledge about standard technologies and upper class technologies which are used for education and instruction purposes (Koehler et al., 2007). This knowledge of teachers is seen as the knowledge of understanding the technological knowledge, using appropriate technology, defining practical technologies, and constantly adapting the changes in technology to the education and instruction environment (Margerum-Leys & Marx, 2002).

Pedagogical knowledge (PK) refers to the knowledge about the methods and applications in relation to learning and teaching (Koehler et al., 2007). This knowledge includes developing instruction strategies, class management, lesson plans, and situations such as student assessment and nature of target mass (Kanuka, 2006).

Content knowledge (CK) includes the knowledge regarding the subject to be taught or learnt (Koehler et al., 2007). This knowledge involves the structures within the related field which connect the cases and events, concepts, theories, processes, and thoughts and opinions with regard to the field with each other, and organise them.

Pedagogical content knowledge (PCK) is the knowledge with regard to the instruction approaches eligible for content and how the elements regarding the content should be arranged for better instruction. PCK emphasises the knowledge of teachers in relation to the learning environment and students' learning (Harris et al., 2009).

Technological content knowledge (TCK) is interested in the attitude in relation to how technology and content influence and restrict each other. The use of different technologies influences different learning by students (Margerum-Leys & Marx, 2002).

Technological pedagogical knowledge (TPK) covers the skill to integrate different and varied technologies into education and instruction methods and use them in an effective way. It is a knowledge which requires associating the knowledge of how to teach with appropriate technologies. It also concerns obtaining knowledge about what kind of changes such association will lead to in education and instruction (Margerum-Leys & Marx, 2002).

Technological pedagogical content knowledge (TPACK) requires understanding the representation and formulation of concepts using technologies, pedagogical techniques that utilise technologies in constructive ways to teach content, and knowledge of what makes concepts difficult or easy to learn. TPACK also requires the use of technology to help address these issues, knowledge of students' prior knowledge and theories of epistemology, and an understanding of how technologies can be utilised to build on existing knowledge and to develop new or strengthen old epistemologies (Koehler et al., 2007).

General theoretical knowledge for TPACK is as given above. However, TPACK shows very little development in theoretical terms. In their research, Cox & Graham (2009) determined that the central structure of the model (TPACK) had different definitions. It is stated that this was because TPACK theory and its subdimensions could not be sufficiently understood and its theoretical structure could not be totally created. Therefore, many studies on TPACK concentrate on TPK, PCK, and TCK in the subdimensions of TPACK. Research conducted shows that teacher training programmes were developed in the PCK dimension and therefore technology could not complete its integration within programmes (Koehler et al., 2007). This bespeaks that the TPACK levels of the teacher candidates who will graduate from teacher training institutions will remain insufficient.

In physics and science instruction, the aim is to teach research and observation approaches through laboratory applications, develop problem solving skills, and help students develop a positive attitude towards these studies (Hanif, Sneddon, Al-Ahmadi, & Reid, 2009). Therefore, the knowledge, skills, and attitudes of the teachers who will be preparing rich stimulant teaching environments for physics and science instruction in relation to the application laboratories with regard to the field should be up to the mark (Lunetta & Tamir, 1978). Researchers and programmers who prepare syllabi for physics and science courses state that the teaching models that should contain experiments within their content are of great importance in students' easier learning of the knowledge, better understanding of the nature of knowledge and science, and development of application skills such as measurement and research, which require proficiency (Gott & Duggan, 1996; Hodson, 1996; Millar, Le Mare´Chal, & Tiberghien, 1999). Therefore, the key laboratory skills which are expected to be gained by teacher candidates are quite important, not only in their pre-service instruction processes but also in their future teaching lives. Students gain key skills which will help them in meaningful learning and developing a positive attitude towards physics in the laboratory environment (Boud, Dunn, & Hegarty-Hazel, 1986). Laboratory purposes and approaches should be understood well by teacher candidates so that physics education can achieve its goals (Jang & Chen, 2010). Therefore, TPACK theory is of great importance for physics and science teacher candidates.

Recent researches show that computer based laboratory applications, computer supported instruction, and interactive computer simulations in physics and science instruction are quite effective on the students' achievements (Chang, Chen, Lin, & Sung, 2008; Foti & Ring, 2008; Geban, Askar, & Ozkan, 1992; Lee, 1999; Lin & Lehman, 1999; Zacharia, 2003). However, the studies which were carried out on teachers' competencies show that laboratories are not used in an effective way and teachers do not use technology sufficiently but continue with traditional methods, even if they have technological knowledge (Lunetta & Tamir, 1978; McCrory-Wallace, 2004). This is considered to have resulted from the fact that teachers do not make sufficient applications with regard to the teaching profession in teacher training institutions, and that they do not gain experience with regard to computer simulations and computer supported laboratory uses. Therefore, there are opinions and applications on giving in-service training courses to teacher candidates after their graduation. However, it is thought that removal of this by the institutions from which teacher candidates graduated will be more effective in solving problems regarding the matter. This research was conducted for the purpose of presenting the TPACK levels of physics and science teacher candidates, determining problems, and offering solutions for them. This research is conducted on physics and science teacher candidates since students learn physics by science teachers in secondary school and by physics teachers in high school. Science teacher candidates take physics courses quite a lot, but not as much as physics teacher candidates do.

The purpose of this research is to investigate whether the TPACK levels of physics and science teacher candidates are sufficient or not. For this purpose, the following questions were asked in the quantitative dimension of the research:

- Are the TPACK levels of the physics and science teacher candidates sufficient, based on Provus' assessment model?
- Is there a significant difference between the TPACK levels of physics and science teacher candidates?
- Do the levels of the physics and science teacher candidates regarding TPACK and its subdimensions significantly affect their academic achievement scores?
- Is there a significant relationship between the levels of the physics and science teacher candidates regarding TPACK and its subdimensions and their academic achievement scores?
- If there is a difference in terms of academic achievement scores between physics and science teacher candidates, do TPACK scores have an effect on this difference?

In the qualitative dimension of the research, in-depth interviews were carried out with teacher candidates.

Method

Participants

The participants consist of senior students who are pursuing their undergraduate degrees in physics and science teacher education programmes and who have completed the majority of their classes in technology, pedagogy, and content areas in a college of education in Turkey. A total of 123 teacher candidates participated in the study. Of those, 66 teacher candidates are from the Department of Physics Teacher Education and 57 participants are from the Department of Science Teacher Education. Furthermore, 54% (n=67) of the participants are males and 46% (n=56) females.

Research Instruments

Technological Pedagogical And Content Knowledge (TPACK) Survey

In this study, a scale regarding college students' perceptions in technological pedagogical and content knowledge (TPACK) domains is used, which was originally developed by Sahin (2011). In the TPACK survey, higher scores for each subscale indicate higher perceived acquaintance with the applications of the knowledge base. The TPACK survey includes seven subscales (technology knowledge, pedagogy knowledge, content knowledge, technological pedagogy knowledge, technological content knowledge, pedagogical content knowledge, and technological pedagogical and content knowledge) with 47 survey items. Sample items of TPACK survey are shown in Table 1.

Table 1. Sample items of TPACK survey

Subscales	**Sample Items (I have knowledge in …)**
Technology Knowledge (TK)	Solving a technical problem with the computer Knowing about basic computer software (ex., Windows, Media Player) and their functions
Content Knowledge (CK)	Knowing about key subjects in my area Developing class activities and projects
Pedagogy Knowledge (PK)	Assessing student performance Using different evaluation methods and techniques
Pedagogical Content Knowledge (PCK)	Developing evaluation tests and surveys in my content area Preparing a lesson plan including class/school-wide activities

Technological Pedagogical Knowledge (TPK)	Choosing technologies appropriate for my teaching/learning approaches and strategies Using computer applications supporting student learning
Technological Content Knowledge (TCK)	Using technologies helping to reach course objectives easily in my lesson plan Preparing a lesson plan requiring use of instructional technologies
Technological Pedagogical and Content Knowledge (TPACK)	Integrating appropriate instructional methods and technologies into my content area Selecting contemporary strategies and technologies helping to teach my content effective

The survey items are on a Likert-type scale with five response choices: “1=no knowledge”, “2=little knowledge”, “3=moderate knowledge”, “4=quite knowledge” and “5=complete knowledge”. In the development study of the instrument, the Cronbach alpha reliability coefficients were found to be between 0.86 and 0.96 for the subscales of the survey, indicating that the instrument is a reliable measure. Also, to determine the achievement levels of the participants, their grade point average (GPA) scores were obtained from the administration office and matched with the survey data.

Interview Form

After the survey study, in-depth interviews were completed in order to support the results of the study and determine the reasons for the differences between the teacher candidates. The participation of five persons each was provided among the physics and science teachers who participated in the survey to this end. Thus, in-depth interviews were conducted with a total of 10 teacher candidates. The selected teacher candidates were randomly selected among teacher candidates who wish to participate in in-depth interviews. Physics teacher candidates were coded as (PH-1, PH-2, PH-3, PH-4, PH-5) and science teacher candidates were coded as (SC-1, SC-2, SC-3, SC-4, SC-5). The following process was used in the in-depth interviews:

- Teacher candidates were primarily asked to describe TPACK theory.
- They were asked if they found their levels sufficient, based on the TPACK theory that they described.
- Teacher candidates were given brief information on TPACK theory by the researcher.

- After the brief information on TPACK, they were directed questions through which they could make self-criticism in line with the answers they had previously given.

Data Analysis

Provus' assessment model was used for the assessment of the data which was obtained as a result of the TPACK survey (Gardner, 1977). Based on this assessment model, the medians of the scores of the teacher candidates regarding each subdimension of the TPACK survey were primarily calculated. The standard scores which are expected from the teacher candidates for each subdimension of the survey were calculated. "I know at good level" and above scores were accepted as the limit for the standard score. The number of items regarding each subdimension of the survey was multiplied with 4 points which were determined for "I know at good level" and the expected standard scores of teacher candidates were calculated. Subsequently, the median scores which have to be received by the teacher candidates with regard to each subdimension of the survey were compared with this standard score. Median scores of the teacher candidates were considered sufficient if equal to or higher than the standard scores determined. Standard scores which were calculated with regard to each subdimension of the survey were determined respectively as (≥60) for TK, (≥24) for CK, (≥24) for PK, (≥28) for PCK, (≥16) for TPK, (≥16) for TCK, and (≥60) for TPACK.

An independent t-test was used to compare college students' TPACK levels based on their departmental affiliation (physics and science). Also, the relationship between student achievement scores and TPACK constructs was analysed. In stepwise linear regression analysis, the relationship between the dependent variable, GPA scores, and the following seven predictor variables was tested: technology knowledge, pedagogy knowledge, content knowledge, technological pedagogy knowledge, technological content knowledge, pedagogical content knowledge, and technological pedagogical and content knowledge. Also, covariance analysis was made in order to test whether the difference between the GPA scores of the teacher candidates, based on their departments, resulted from TPACK scores. Data was analysed by using SPSS (Statistical Package for Social Sciences) 15.0 software.

From the data which was acquired from the in-depth interviews with teacher candidates, results were obtained based on common attitudes, thoughts, and opinions. The results were used in the discussion and result sections of the research in order to support the quantitative findings in relation to the TPACK levels of the teacher candidates, and present the problems and their reasons in relation to attitudes towards TPACK. The findings were coded with regard to the opinions of the teacher candidates who participated in the research.

Findings

Median values of the scores and required standard score values of the teacher candidates received from the subdimensions of the TPACK survey based on their departments are shown in Table 2. As evident from the table, the median values regarding TPACK and its subdimensions are below the expected standard value. Only the physics teacher candidates were seen in the sufficient level in the TPK dimension.

Table 2. TPACK competence of departments based on Provus' assessment model

Subscale	Department	N	Performance Median	Standard
TK	Physics	66	58	≥60
	Science	57	51	
CK	Physics	66	20	≥24
	Science	57	19	
PK	Physics	66	21	≥24
	Science	57	20	
PCK	Physics	66	25	≥28
	Science	57	24	
TPK	Physics	66	16*	≥16
	Science	57	14	
TCK	Physics	66	14.5	≥16
	Science	57	12	
TPACK	Physics	66	18	≥20
	Science	57	17	

Table 3 presents the independent t-test and the comparison of the scores regarding TPACK and its subdimensions with GPA scores of the physics and science teacher candidates. As shown from the results of the analysis, physics teacher candidates are more successful when compared to science teacher candidates in terms of their

TK, CK, TPK, TCK, TPACK, and GPA scores (P<0.05). No significant difference could be found between the physics and science teacher candidates in terms of PK and PCK scores (P>0.05).

Table 3. Physics and science teacher candidates' TPACK and GPA scores according to department

Subscale	Department	N	Mean	Performance Median	Std. Deviation	t	p
TK	Physics	66	58.6212	58	6.90098	6.966	.000
	Science	57	49.2105	51	8.08380		
CK	Physics	66	20.4394	20	3.09903	3.689	.000
	Science	57	18.1053	19	3.91282		
PK	Physics	66	20.6061	21	3.56858	0.957	.341
	Science	57	19.9298	20	4.27142		
PCK	Physics	66	24.3485	25	4.86587	0.596	.552
	Science	57	23.8246	24	4.85917		
TPK	Physics	66	15.4545	16	2.59693	4.660	.000
	Science	57	13.0526	14	3.11919		
TCK	Physics	66	14.2576	14.5	2.74737	4.276	.000
	Science	57	12.0175	12	3.06181		
TPACK	Physics	66	17.5455	18	3.65506	2.017	.046
	Science	57	16.2456	17	3.45523		
GPA Scores	Physics	66	2.9285	2.97	0.48370	5.672	.000
	Science	57	2.4693	2.49	0.40190		

As demonstrated in Table 4, TPACK scores of the teacher candidates influence their academic achievements in a positive way. As a result of regression analysis, it was found that TPACK and its subdimensions influenced teachers' achievement scores in a positive way at the rate of 18% (R2=0.178). The more the TPACK scores of the teacher candidates increase, the more their academic achievements increase (F=3.547, P<0.002).

Table 4. Prediction of physics and science teacher candidates' GPA scores by their TPACK constructs

Model		Sum of Squares	df	MeanSquare	F	Sig.
1	Regression	5.452	7	0.779	3.547	.002(a)
	Residual	25.250	115	0.220		
	Total	30.702	122			
a)Predictors: TPACK, TK, CK, PK, TCK, TPK, PCK; b)Dependent Variable: GPA scores						

In Table 5, a positive and linear but a weak relationship is illustrated between the GPA scores and TPACK, TCK, TPK, TK, and CK scores of the teacher candidates (P<0.01). No relationship was found between the GPA scores and PK and PCK scores (P>0.05). It is obvious that there is a significant, linear, and high relationship between the TPACK scores and all subdimensions of TPACK (P<0.01).

Table 5. Correlations between physics and science teacher candidates' GPA and TPACK scores

	TK	CK	PK	PCK	TPK	TCK	TPACK	GPA_scores
TK	1							
CK	.576(**)	1						
PK	.344(**)	.657(**)	1					
PCK	.307(**)	.603(**)	.780(**)	1				
TPK	.619(**)	.649(**)	.579(**)	.658(**)	1			
TCK	.612(**)	.649(**)	.588(**)	.687(**)	.790(**)	1		
TPACK	.390(**)	.603(**)	.738(**)	.834(**)	.716(**)	.709(**)	1	
GPA_scores	.302(**)	.328(**)	.162	.137	.335(**)	.278(**)	.253(**)	1
**. Correlation is significant at the .01 level (2-tailed).								

In Table 6, the results of the covariance analysis which shows whether the difference between the GPA scores of the teacher candidates arose from their TPACK scores based on their departments are presented. As shown in the table, the TPACK score is also effective in the generation of the difference between the GPA scores of the physics and science teacher candidates (F=5.481, P<0.05). The GPA scores of the groups which were corrected as a result of a covariance (Ancova) analysis are shown in Table 7.

Table 6. Covariance analysis which shows whether the difference between the GPA scores of the teacher candidates arose from their TPACK scores

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	7.730(a)	3	2.577	13.348	.000	.252
Intercept	26.170	1	26.170	135.568	.000	.533
Department	1.150	1	1.150	5.958	.016	.048
TPACK	1.058	1	1.058	5.481	.021	.044
Department * TPACK	.363	1	.363	1.879	.173	.016
Error	22.972	119	.193			
Total	937.825	123				
Corrected Total	30.702	122				
R Squared = .252 (Adjusted R Squared = .233)						

Table 7. Physics and science teacher candidates' estimated marginal GPA scores

Dependent Variable: GPA scores				
Department	**Scores**	**Recovered Scores**	**Std. Error**	**95% Confidence Interval**
Physics	2.928	2.922(a)	.055	2.813 - 3.030
Science	2.469	2.499(a)	.059	2.381 - 2.616

(a) Covariates appearing in the model are evaluated at the following value: TPACK = 16.9431.

Accordingly, students will be more successful if they have strong TPACK. In the literature, the relationship between self-efficacy and academic achievement is indicated as significant (Bandura, 1993; Zimmerman & Bandura, 1994), and self-efficacy is associated with semester and final grades (Pintrich & De Groot, 1990).

Discussion and conclusions

As a result of the assessment which was made based on Provus' assessment model, the median scores of the physics and science teacher candidates who participated in the research, which were received from the TPACK and its subdimensions, remained below the standard scores. Only the physics teacher candidates were found in the sufficient level in the TPK dimension.

On the other hand, based on the result of the independent t-test, significant differences were found in favour of physics teacher candidates between the GPA scores and TPACK scores of the physics and science teacher candidates. Also, significant differences were found in favour of physics teacher candidates in TK, CK, TPK, and TCK steps, which are the subdimensions of TPACK.

As a result of the Ancova analysis, it was found that the physics and science teacher candidates had a significant effect on the difference between the GPA scores of the groups. Moreover, as a result of the correlation analysis, it was discovered that there was a positive and linear relationship between the GPA scores and TPACK, TCK, TPK, TK, and CK scores of the teacher candidates. This result shows that the attitudes regarding TPACK and its subdimensions affected academic achievement in a positive way. In the study by Erdogan & Sahin (2010) on the teacher candidates who study in the department of mathematics, the students with higher TPACK levels were found to be more successful.

Even though the findings of the research show significant results in favour of physics teacher candidates, it was determined that the TPACK levels of the teacher candidates in both departments were insufficient, based on Provus' assessment model. In order to determine how the differences between the two groups arose and from what this insufficiency in the TPACK levels of the teacher candidates resulted, in-depth interviews were conducted with five persons from both the physics and science teacher candidates, respectively, who participated in the research.

None of the teacher candidates fully answered the first question (What is TPACK in your opinion?) which was directed to them in the in-depth interviews. Teacher candidates generally considered technological knowledge, pedagogical knowledge, and content knowledge independent from each other when replying to this question. Teacher candidates listed the computer programs which should be known and technological tools which should be used by teachers in terms of technological knowledge. They discussed the lesson names with regard to pedagogy that they received as pedagogic knowledge during education and instruction, and teaching methods which can be used by the teacher while teaching the lesson. As content knowledge, physics teacher candidates tried to list the units and titles in the high school physics syllabus, while science teacher candidates tried to list the units and titles in the science syllabus.

Secondly, the teacher candidates were asked whether they found themselves sufficient, based on the TPACK theory they described. Teacher candidates considered TPACK structure as knowledge independent from each other, as in the first question, while they were evaluating their TPACK sufficiency levels. Based on the evaluations they made, teacher candidates answered in line with their self-confidences. Accordingly, while five teacher candidates (PH-1, PH-2, PH-5, SC-2, SC-3) said that they were at a sufficient level in terms of their content knowledge, other teacher candidates emphasised that they had some deficiencies in terms of content knowledge but they could overcome them by studying. None of the teachers emphasised the relationship between technology and content with pedagogy. Furthermore, the studies which were made with regard to the instructional applications of education technologies by K-12 teachers show that the applications made by teachers are deficient in pedagogical terms, limited in terms of breadth, diversity, and depth, and could not perform integration with programme-based teaching and learning well (Earle, 2002; Kiray & Kaptan, 2012; McCrory-Wallace, 2004; Zhao, Pugh, Sheldon, & Byers, 2002).

Seven teacher candidates (PH-1, PH-2, PH-3, PH-5, SC-2, SC-3, SC-4) said that they found themselves sufficient in terms of pedagogical knowledge. However, all of the teacher candidates stated that their teaching experiences were not sufficient and this experience could only be gained after starting teaching. Another situation which was stated by the teacher candidates in this respect was that the applied courses which are made for teaching experience were not sufficiently applied. They asserted that teachers did not show sufficient interest in them and usually took the attendance and let them go in applied courses at the schools which they went to as interns. Teacher candidates stated that the public personnel selection examination, which is made in Turkey and required for becoming a teacher, contained questions evaluating pedagogical knowledge, therefore they memorised pedagogical knowledge. Two teacher candidates (PH-2, PH-5) said that pedagogical knowledge is related to the content knowledge to be taught but they could not reflect this in lessons because the instructors, who come from other departments, do not have knowledge in relation to the content. Two teacher candidates (PH-3, SC-1) emphasised that teachers needed to have the skills and talents to determine the previous knowledge of students and which intelligence type they had, within their pedagogical knowledge. As it can be understood from the above-mentioned opinions, they consider pedagogical knowledge only as a theoretical knowledge which must be learned. Most of all, it is understood that they cannot comprehend what PCK knowledge is. With PCK knowledge, teachers should be able to determine the learning requirements of the students and their understanding styles, and select and apply an effective teaching method which can transfer the required content knowledge (Chauvot, 2008; Dawkins, Dickerson, McKinney, & Butler, 2008; Piccolo, 2008).

Teacher candidates considered TPACK theory as knowledge independent from each other and defended that technological knowledge is a further knowledge, stating that technological knowledge can be provided through the person's own efforts. They considered this knowledge to be related to the person's interest in technology. In his study, Vacirca (2008) emphasised that the interest in technology is important in the development of technological knowledge. In particular, the female students who participated in the interview (PH-2, PH-5, SC-1, SC-3) stated that they had difficulty in using computers and other technological tools which can be used by the teacher in the classroom (Vacirca, 2008). All teacher candidates stated that the availability of personal computers and the internet could substantially contribute to the development of technological knowledge. Male teacher candidates had more self-confidence in this regard. They stated that they understood computers well and they usually made the settings of the technological tools which are used in the classroom activities themselves. However, as it can be understood from the interviews, teacher candidates were asked about their knowledge and experiences in reaching and accessing materials such as simulation, animation, and video, which they can use in the web environment. Physics teacher candidates were seen to be more interested in these issues. The elective courses regarding computer supported instruction in physics instruction are considered to be effective in this. Teacher candidates, except for SC-2 among physics teacher candidates, stated that they did not perform sufficient researches or projects in relation to simulation, animation, or educative computer programs. The researches which have been performed in the last ten years indicate that computer simulations are of great importance in physics education and instruction and that they provide important advantages. Besides these researches, the investigations regarding teacher competences show that some teachers were afraid of change and continued using traditional teaching methods although they were familiar with technology. This is because of the teachers' deficiencies in technological knowledge and their practices regarding the use of technology (Kent, 2006; Smith, Higgins, Wall, & Miller, 2005). Although the integration of technology with education and training is emphasised, the studies show that teacher training programmes are unable to prepare the teacher candidates in an appropriate manner in terms of the integration of technology, and that many teachers used technology unwillingly in their lessons (Moursund & Bielefeldt, 1999; Willis & Mehlinger, 1996; Zhao et al., 2002). They also show that even though lessons with technological content offer opportunities with regard to introducing teacher candidates to different technological tools and how to use them, teacher candidates are unable to sufficiently employ them in application lessons and make successful presentations (Hew & Brush, 2007; Vannatta & Beyerbach, 2000).

Following the above questions, the teacher candidates were given a brief explanation about what TPACK knowledge is. After this explanation, the teacher candidates were asked the third question which is "Do you think your TPACK knowledge is sufficient?" After the explanation, all of the teacher candidates who previously considered themselves sufficient or deficient stated that TPACK knowledge was a more complicated knowledge and that they felt themselves insufficient. As the interview continued, the teacher candidates started to concentrate on how to develop TPACK knowledge rather than questioning their TPACK knowledge. Two physics teacher candidates (PH-3, PH-5) stated that they had courses with regard to technological knowledge and pedagogical knowledge in their departments, but they did not have any courses which provided TPACK knowledge in detail. Physics teacher candidates stated that elective courses included courses and projects close to the discourses in relation to TPACK, but that was not sufficient. Two science teacher candidates (SC-2, SC-4) stated that they had pedagogical courses as well as courses in which technological and content knowledge were considered together but they did not have any applied courses in which the three of them were considered simultaneously. Furthermore, science teacher candidates complained about the insignificance of the technological dimension of the courses. They stated that they were not usually taught as web focused or experimental in their courses, and they had classroom activities and demonstration experiments but those were simple and unattractive. Five teacher candidates (PH-1, PH-5, SC-1, SC-2, SC-3) emphasised that instructors also had to perform sample applications in their courses so that TPACK knowledge could be gained. The same teacher candidates supposed that the TPACK knowledge of most of the instructors is insufficient based on the definition of TPACK knowledge given. Seven teacher candidates (PH-1, PH-2, PH-5, SC-2, SC-3, SC-4, SC-5) suppose that it should be added within the syllabus as a new course so that this knowledge can be acquired. They believe that TPACK knowledge itself should mainly be a course to be given, and this course should be taught by the educators who are good at physics or science subjects. Two science teacher candidates (SC-1, SC-4) recommended that guiding books should be written so that TPACK knowledge can be improved. They stated that a crammer, which is in a suggestive level to teachers and teacher candidates, should be prepared, although not for all subjects in the syllabus. Two teacher candidates (PH-4, SC-5) stated that instructors only educated through presentation in their courses and these courses were prepared and taught by the teacher candidates themselves. They stated that the courses which were given in this way were usually memorised and that they were evaluated in the form of test or in written form. The same teacher candidates suppose that TPACK knowledge can be gained by being supported by projects and active applications following the related education and instruction.

It was understood from the interviews which were conducted with the teacher candidates that physics teacher candidates had more elective courses with regard to physics education. Upon the examination of the syllabus, it was found that physics teacher candidates had more elective courses and that these courses were rich in technological knowledge. This may indicate why physics teacher candidates were more successful in the dimensions other than PK and PCK (TK, TPK, TCK, TPACK) when compared to science teacher candidates.

Suggestions

From the interviews, it can be understood that one of the reasons why the TPACK levels of the teacher candidates are insufficient is because teacher candidates do not sufficiently know TPACK theory and students have not previously encountered such knowledge. This is because teacher candidates are not given sufficient knowledge about the existence of TPACK theory and applications of the theory are not performed. This problem can only be removed by creating an applied course in which knowledge on TPACK theory is provided, and adding this course to the syllabus. Another problem observed in many studies is that technology experiences problems with PCK in the universities that train teachers. This can only be eliminated by understanding and applying TPACK theory. However, in the studies, there are many situations in which TPACK theory cannot be fully understood, and educators cannot meet at a common point in TPK, PCK, and TCK levels. Therefore, a comprehensive book can be prepared by means of the studies which can meet on a common opinion by examining previous studies with regard to TPACK theory. Examples regarding the contents in the books will also give substantial ideas to both teacher candidates and instructors. It is obvious that although there are books on conveying TPACK theory, these books cannot fully express the junction points of the theory as they are not prepared specific to every field and do not include examples. It is of great importance that the book has a content which involves sample applications specific to the fields. Another deficiency with respect to TPACK is that the education courses made are not sufficiently application oriented and project directed. This shows that teacher candidates are deficient in terms of applications with regard to how technology and pedagogy are involved in the content knowledge, even though they do not know what TPACK theory is. The studies show that, thanks to the use of computer technologies with low cost interfaces in the laboratory environment, students conduct their physics and science experiments in an easy and understandable way. Many studies presented that the moving graphics shown simultaneously by means of the data transferred to the computer through interfaces helped students to better organise cases and events regarding physics, and the computer simulations prepared for physics and science instruction had an effect on the conceptual improvements of the students (Clark & Jorde, 2004; Dejong & Van Joolingen, 1998; Monaghan & Clement, 1999; Sun, Lin, & Yu, 2008; Zacharia, 2005; Zacharia, Olympiou, & Papaevripidou, 2008). However, the insignificance of the experiences of the teacher candidates with regard to these applications indicates that they will have a tendency to use traditional methods in their future teaching career. In order to overcome this, physics and science laboratories at the universities should be improved, computer based testing apparatuses should be increased, and there should be elective courses with regard to the use of computer simulations. Furthermore, it is considered that the teachers who graduated lacking in such knowledge should be taken into in-service training courses for improvement purposes. This is because the common opinion is that when an innovative programme is prepared and presented to the teachers and they are informed about how to implement it, the teachers will teach their lessons through the methods which are prepared in line with this programme. However, the teacher also needs conceptual understanding in order to teach conceptually (McEwan & Bull, 1991). Therefore, the content and scope of the training courses to be prepared should be considered in-depth and there should be a long-term application process.

References

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist*, 28(2), 117-148.

Boud, D., Dunn, J., & Hegarty-Hazel, E. (1986). *Teaching in laboratories*. Guildford: Society for Research into Higher Education & NFER-Nelson.

Chang, K. E., Chen, Y. L., Lin, H. Y., & Sung, Y. T. (2008). Effects of learning support in simulation-based physics learning. *Computers & Education*, 51(4), 1486-1498.

Chauvot, J. B. (2008). Curricular knowledge and the work of mathematics teacher educators. *Issues in Teacher Education*, 17(2), 83-99.

Clark, D., & Jorde, D. (2004). Helping students revise disruptive experientially supported ideas about thermodynamics: Computer visualizations and tactile models. Journal of Research in Science Teaching, 41(1), 1-23.

Cox, S., & Graham, C. R. (2009). Diagramming TPACK in practice: Using an elaborated model of the TPACK framework to analyze and depict teacher knowledge. *TechTrends*, 53(5), 60-69.

Dawkins, K. R., Dickerson, D. L., McKinney, S. E., & Butler, S. (2008). Teaching density to middle school students: Preservice science teachers' content knowledge and pedagogical practices. *Clearing House*, 82(1), 21-26. Dejong, T., & Van Joolingen, W. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, 68(2), 179-201.

Earle, R. S. (2002). The integration of instructional technology into public education: Promises and challenges. *ET Magazine*, 42(1), 5-13. Retrieved on 24th March 2013 from http://bookstoread.com/etp/earle.pdf

Erdogan, A., & Sahin, I. (2010). Relationship between math teacher candidates' technological pedagogical and content knowledge (TPACK) and achievement levels. *Procedia - Social and Behavioral Sciences*, 2(2), 2707-2711.

Foti, S., & Ring, G. (2008). Using a simulation-based learning environment to enhance learning and instruction in a middle school science classroom. *Journal of Computers in Mathematics and Science Teaching*, 27(1), 103-120.

Gardner, D. E. (1977). Five evaluation frameworks: Implications for decision making in higher education. *The Journal of Higher Education*, 48(5), 571-593.

Geban, O., Askar, P., & Ozkan, I. (1992). Effects of computer simulations and problem-solving approaches on high school students. *Journal of Educational Research*, 86(1), 5-10.

Gott, R., & Duggan, S. (1996). Practical work: Its role in the understanding of evidence in science. *International Journal of Science Education*, 18(7), 791-806.

Hanif, M., Sneddon, P. H., Al-Ahmadi, F. M., & Reid, N. (2009). The perceptions, views and opinions of university students about physics learning during undergraduate laboratory work. *European Journal of Physics*, 30(1), 85-96.

Harris, J., Mishra, P., & Koehler, M. J. (2009). Teachers' technological pedagogical content knowledge: Curriculum-based technology integration reframed. *Journal of Research on Technology in Education*, 41(4), 393–416.

Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development*, 55(3), 223-252.

Hodson, D. (1996). Laboratory work as scientific method: Three decades of confusion and distortion. *Journal of Curriculum Studies*, 28(2), 115-135.

Jang, S. J., & Chen, K. C. (2010). From PCK to TPACK: Developing a transformative model for pre-service science teachers. *Journal of Science Education and Technology*, 19(6), 553-564.

Kanuka, H. (2006). Instructional design and e-learning: A discussion of pedagogical content knowledge as a missing construct. *The e-Journal of Instructional Science and Technology*, 9(2). Retrieved on 24th March 2013 from http://www.ascilite.org.au/ajet/e-jist/docs/vol9_no2/papers/full_papers/kanuka.pdf

Kent, P. (2006). Using interactive whiteboards to enhance mathematics teaching. *Australian Primary Mathematics Classroom*, 11(2), 23-26.

Kiray, S. A., & Kaptan, F. (2012). The effectiveness of an integrated science and mathematics programme: Science-centred mathematics-assisted integration. *Energy Education Science and Technology Part B: Social and Educational Studies*, 4(2), 943-956.

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, 49(3), 740-762.

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta-analysis. *International Journal of Instructional Media*, 26(1), 71-85.

Lin, X., & Lehman, J. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own learning. *Journal of Research in Science Teaching*, 36(7), 837-858.

Lunetta, N. V., & Tamir, P. (1981). An analysis of laboratory activities: Project physics and PSSC. *School Science and Mathematics*, 81(8), 635-642.

Margerum-Leys, J., & Marx, R. W. (2002). Teacher knowledge of educational technology: A case study of student/mentor teacher pairs. *Journal of Educational Computing Research*, 26(4), 427-462.

McCrory-Wallace, R. (2004). A framework for understanding teaching with the internet. *American Educational Research Journal*, 41(2), 447-488.

McEwan, H., & Bull, B. (1991). The pedagogic nature of subject matter knowledge. *American Educational Research Journal*, 28(2), 316-324.

Millar, R., Le Mare´Chal, J. F., & Tiberghien, A. (1999). 'Mapping' the domain: Varieties of practical work. In J. Leach & A. C. Paulsen (Eds.), *Practical work in science education* (pp. 33-59). Roskilde: Roskilde University Press.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A new framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054.

Monaghan, J., & Clement, J. (1999). Use of a computer simulation to develop mental simulations for understanding relative motion concepts. *International Journal of Science Education*, 21(9), 921-944.

Moursund, D., & Bielefeldt, T. (1999). *Will new teachers be prepared to teach in a digital age? A national survey on information technology in teacher education* /online/. Retrieved on 24th March 2013 from http://www.mff.org/pubs/ME154.pdf

Piccolo, D. (2008). Views of content and pedagogical knowledges for teaching mathematics. *School Science and Mathematics*, 108(2), 46-48.

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82(1), 33-40.

Sahin, I. (2011). Development of survey of technological pedagogical and content knowledge (TPACK). *TOJET: The Turkish Online Journal of Educational Technology*, 10(1), 97-105.

Schmidt, D., Baran Sahin, E., Thompson, A., & Seymour, J. (2008). Developing effective technological pedagogical and content knowledge (TPACK) in PreK-6 teachers. *Proceedings of Society for Information Technology & Teacher Education International Conference* (pp. 5313-5317). Chesapeake, VA: AACE.

Smith, H. J., Higgins, S., Wall, K., & Miller, J. (2005). Interactive whiteboards: Boon or bandwagon? A critical review of the literature. *Journal of Computer Assisted Learning*, 21(2), 91-101.

Sun, K., Lin, Y., & Yu, C. (2008). A study on learning effect among different learning styles in a web-based lab of science for elementary school students. *Computers & Education*, 50(4), 1411-1422.

Vacirca, E. (2008). How do teachers develop their technological pedagogical content knowledge in the context of system-wide pedagogical and curriculum reform? *AARE 2008 International Education Research Conference – Brisbane*, Retrieved from http://www.aare.edu.au/08pap/vac08335.pdf

Vannatta, R. A., & Beyerbach, B. (2000). Facilitating a constructivist vision of technology integration among education faculty and pre-service teachers. *Journal of Research on Computing in Education*, 33(2), 132-148.

Willis, J., & Mehlinger, H. D. (1996). Information technology and teacher education. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 978-1029). New York: Macmillan,.

Zacharia, Z. C. (2003). Beliefs, attitudes, and intentions of science teachers regarding the educational use of computer simulations and inquiry-based experiments in physics. *Journal of Research in Science Teaching*, 40(8), 792-823.

Zacharia, Z. C. (2005). The impact of interactive computer simulations on the nature and quality of postgraduate science teachers' explanations in physics. *International Journal of Science Education*, 27(14), 1741-1767.

Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching*, 45(9), 1021-1035.

Zhao, Y., Pugh, K., Sheldon, S., & Byers, J. L. (2002). Conditions for classroom technology innovations. *Teachers College Record*, 104(3), 482-515.

Zimmerman, B. J., & Bandura, A. (1994). Impact of self-regulatory influences on writing course attainment. *American Educational Research Journal*, 31(4), 845-862.