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# Bursa Uludağ Üniversitesi Eğitim Fakültesi Dergisi

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Araştırma Makalesi

<https://dx.doi.org/10.19171/uefad.533233>

Başvuru/Received: 02.02.2018 Kabul/Accepted: 11.11.2018

## Enabling Pre-service Chemistry Teachers' Development of Technological, Pedagogical, and Content Knowledge (TPACK) through Case-Based Lesson Planning

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### ABSTRACT

This study aimed to enable technological, pedagogical, and content knowledge (TPACK) development among pre-service teachers based on case-based lesson planning. A total of 21 pre-service chemistry teachers having a bachelor's degree participated in the study during their pedagogical certificate program in Turkey. Data were collected using analysis of instructional plans and open-ended questions. Results showed that case-based lesson planning provided a successful context for helping pre-service teachers to develop content knowledge (CK), technological knowledge (TK), pedagogical knowledge (PK), and TPACK knowledge as the basis for designing effective technology-integrated chemistry lessons.

**Key Words:** TPACK, case-based teaching, chemistry instruction, teacher education.

## **INTRODUCTION**

There has been a great deal of attention given to improving the teaching and learning of chemistry and other sciences. One of the fundamental aims of chemistry is to explain the structure of matter and its transformations (Causa, Savin, & Silvi, 2014). Chemistry education involves three levels of understanding: (1) the macroscopic level, where topics are expressed in terms of phenomena visible in our world such as changes in materials and substances, colour changing, density, state of matter, and so on; (2) the microscopic (sometimes called submicroscopic) level, where topics are expressed in terms of molecules, atoms, ions, and so on; and (3) the symbolic level, where the meanings of topics are expressed in terms of formulas equations, ionic drawings, and so on (Gabel, 1993; Johnstone, 1991; Talanquer, 2011). These three levels have guided chemistry instructors, curriculum and software developers, and textbook writers for many years (Talanquer, 2011). Numerous studies have reported that many chemistry learners have difficulty in understanding the macroscopic and microscopic levels of chemistry as the topics are generally related to the structure of matter (Sirhan, 2007; Tatlı & Ayas, 2013) and because students perceive chemistry subjects as not being applicable outside of school due to the abstract nature of the subject (Stieff & Wilensky, 2003).

Several factors affect students' ability to learn chemistry, and these in turn affect instructional approaches that may be effective. For example, Scantlebury (2008) stated that student achievement is highly dependent on the teacher's content knowledge, in addition to the teachers' knowledge of learners and their socio-cultural context, as well as the curriculum and teaching methods. Another important factor affecting students' learning of chemistry is the skill of visualization. Visualization is used in the learning of abstract concepts, especially as they occur at the micro level. The learner's visual capability can be developed in all levels for a deeper understanding of the concepts in chemistry (Locatelli, Ferreira, & Arroio, 2010). Animated models are useful for teaching chemistry at the micro- and macro levels (Doymuş, Şimşek, & Karaçöp, 2009). However, many studies have indicated that using animations must be done with appropriate instructional methods in order to improve student understanding. Therefore, different instructional methods employing animations to promote understanding have been considered. To achieve the goal of developing students' visualization skills, chemistry educators must allocate substantial time to develop their lessons that help students visualize the abstract concepts and bridge between the chemistry subjects and real world applications (Stieff & Wilensky, 2003). As well, case studies offer students opportunities to relate science with their

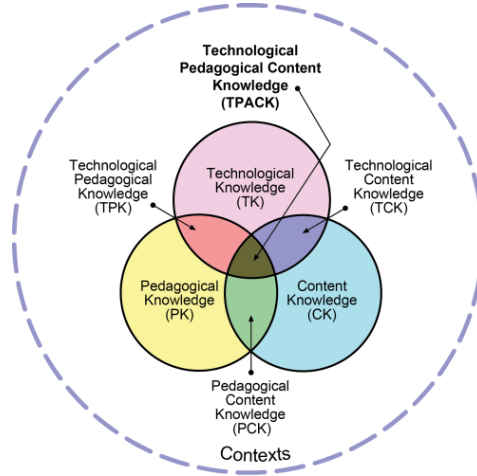
daily lives (Camill, 2006; Yadav, Shaver, & Meckl, 2010). Case method instruction begins with a detailed description of an authentic problem situation that the learners analyze. Students then work to propose solutions for the problem. This sequence is often followed by a series of questions regarding the relationship of the proposed solution to the original problem, which allows students to demonstrate their new understanding (Boubouka, Verginis, & Grigoriadou, 2008).

There is currently also a great deal of attention on the effective integration of technology in K–12 instruction (Hofer & Grandgenett, 2012), including in the teaching of chemistry (Chittleborough, 2014). In order to do that, teachers need to coordinate their lesson planning with the curriculum requirements, students' learning needs, available technologies, and the authenticities of school and classroom settings (Harris & Hofer, 2011). Prospective teachers generally take courses in technology, content knowledge, and pedagogical content independently of each other during their undergraduate education. For example, teacher candidates can take courses such as general chemistry, computer programming, instructional technology, and material design and subject-specific teaching methods in different terms. This separation can lead to difficulties in which topics and appropriate teaching methods that should be designed for use together are addressed separately in planning. To address the challenges and to successfully integrate educational technologies into the classroom, the concept of Technological Pedagogical and Content Knowledge (TPACK) has been developed as a way of describing and emphasizing the interconnections among these areas. Attention to the development of teachers' TPACK leads to fundamental changes in the way teacher candidates approach planning for instruction (Chai, Koh, & Tsai, 2013; McGrath, Karabas, & Willis, 2011).

## **Theoretical Background**

Shulman (1986) introduced the idea of pedagogical content knowledge (PCK), arguing that that pedagogical knowledge and content knowledge influence each other. Subsequently, Mishra and Koehler (2006) proposed that technological knowledge (TK) be added as a third domain of knowledge in the PCK framework, as a result of the increased usage of educational tools and resources in classrooms. Adding this third domain, creates the concept of technological pedagogical and content knowledge (TPACK, sometimes written TPCK). As an integrated framework of teacher knowledge, TPACK addresses the effective integration of technology, and especially information and communication technology (ICT), into teaching

and learning activities. Mishra and Koehler (2006) also described TPACK as the connections that teachers make between their technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). This leads to considerations of combined knowledge domains, such as pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK), which means that TPACK is the result of the interaction of these three basic forms of knowledge. Figure 1 shows the visual representation of the relationship among the seven constructs.



**Figure 1.** TPACK Framework (Koehler & Mishra, 2009, p. 63)

A brief description of each body of knowledge is given below, along with examples from the literature review (Chai, Koh, & Tsai, 2013, p. 33; Harris, Mishra, & Koehler, 2009; Koehler & Mishra, 2005; Koehler et al., 2014; Mishra & Koehler, 2006) as shown in Table 1.

**Table 1.** Description of TPACK constructs

<b>Dimension</b>	<b>Description</b>	<b>Example</b>
TK	Knowledge about both standard and more advanced technologies.	Knowledge about how to use Web 2.0 tools (e.g., wikis, blogs, Facebook).
PK	Teachers' deep knowledge about the processes and practices or methods of teaching and learning, lesson planning, and student assessment.	Knowledge about how to use a 5E Learning Cycle (Bybee & Landes, 1990; Trowbridge & Bybee, 1990) method in teaching. For example, to know what kind of applications will be done in the steps of engage, explore, explain, elaborate, and evaluation on the chemical reactions topic.
CK	Knowledge about the subject matter to be learned.	Teachers level of the chemistry content, such as reaction types, that they are going to teach.
PCK	Knowledge of pedagogy that is applicable to teaching a specific content.	Knowledge of how to use water flow analogies to teach electricity.
TPK	Knowledge about how teaching and learning can change when particular technologies are used in specific ways.	Computer-supported collaborative learning For example, how to use computer technologies (i.e.web 2.0) to increase active learning, or for communicating with students
TCK	Knowledge about which specific technologies are best suited for addressing subject-matter learning in the domains being taught.	Using a specific technology, such as animations, to illustrate molecular movement, which can change how students apply and understand the particular concepts, such as states of matter.
TPACK	Knowledge for effective teaching with technology, requiring an understanding of the representation of concepts using technologies, and pedagogical techniques that use technologies in constructive ways to teach specific content.	Knowledge about how to use a wiki as a communication tool to enhance collaborative learning in which students explore applications of chemistry principles

TK:Technological Knowledge, PK:Pedagogical Knowledge, CK:Content Knowledge, PCK:Pedagogical Content Knowledge, TPK: Technological Pedagogical Knowledge, TCK: Tecnological Content Knowledge, TPACK:Tecnological Pedagogical Content Knowledge

## Related Literature

Many studies show that the TPACK framework already has had a substantial impact on the field of teacher education. Numerous studies, for example, have been conducted for describing the use of the TPACK to design, develop, and deliver pre-service and in-service teacher education

through various professional development applications. Several studies of the TPACK framework have gained positive effects in terms of content, pedagogical, technological, and TPACK knowledge.

Chai, Koh, and Tsai (2010) examined the TPACK perceptions of 889 pre-service teachers entering the Postgraduate Diploma in Education (secondary) Programme at a Singapore teacher education institution before and after attending an ICT course designed to implement components of the TPACK framework. The researchers found that the pre- and post-course surveys have significant differences regarding the TK, PK, CK, and TPACK of pre-service teachers with moderately large effect sizes. When the interactions between the domains were analyzed, the findings suggested that PK have the largest impact on TPACK.

Hofer and Grandgenett (2012) examined the pre-service teachers' development of TPACK over an 11-month-long initial certification program in a secondary teacher education program. Comparisons of self-reported surveys, structured reflections, and instructional plans at multiple data points spanning the three-semester program revealed significant development of the participants' TPK and TPACK, but only limited growth in TCK.

Harris and Hofer (2011) investigated the development of TPACK through instructional planning of seven experienced secondary social studies teachers, from six different states of the USA. As a result of the study teachers mentioned that they became aware of new learning activities and their awareness of technology integration increased.

Khan (2011) examined how a science teacher taught chemistry using computer simulations and its impact on the students. The researcher collected data using teacher interviews and student surveys and analyzed the data using TPACK as a theoretical framework. The researcher found that student engagement with simulations enhanced conceptual understanding of chemistry. The researcher stated that when teachers are able to design TPACK-integrated lesson, students' learning could be enhanced.

Polly (2011) examined two in-service teachers with respect to Technology Integration in Mathematics (TIM), which is a year-long professional development project funded at a major university in the southeastern United States. Teachers were engaged in 48 hours of workshops focusing on using technology standards-based pedagogies (e.g., rich mathematical tasks, questioning strategies) to teach mathematics. Analysis of the data indicated that both teachers demonstrated aspects of TPACK during the integration of high-level technology-rich tasks. However, even

during technology activities, teachers' enacted pedagogies did not align with those emphasized during the professional development.

Research very similar to the present study was conducted by Mouza and Klein-Karcmer (2013). In this study the researchers aimed to determine how case development, which specifically focuses on designing, enacting, and reflecting on technology-integrated classroom experiences, helps pre-service teachers recognize relationships among technology, content, and pedagogy. The primary data sources were participants' case reports and associated lesson plans. Thus, a complete data set from each participant included a technology-integrated lesson designed during his/her participation in the course and the accompanying case report. Each lesson plan was coded using the Technology Integration Assessment Rubric to evaluate pre-service teachers' lesson plans. Results indicated that case development provided a successful context for helping pre-service teachers bring together different knowledge bases to design and implement effective technology-integrated lessons. Results also indicated that some participants have demonstrated only emergent TPACK; they exhibited a disconnection between knowledge evidenced in their lesson plans and application of knowledge evidenced in their case reports. This finding is hardly surprising, since it is reasonable that teachers acquire TPACK progressively and do not suddenly display this knowledge in their professional practice.

Yadav (2008) examined sixteen pre-service teachers' perceptions of the impact of video cases and how they were implemented in a literacy methods course. In the study a video case-based software called Interactive Video Analysis Neighborhood (IVAN), which allows teacher educators to link video cases to the other relevant articles, teacher comments, and student products, was used for literacy methods course. The researcher found that pre-service teachers overall had a positive experience with video cases in terms of their learning process.

Canbazoğlu Bilici, Guzey and Yamak (2016) investigated the pre-service science teachers' TPACK through observations and lesson plans. They found that a TPACK-focused science methods course has affected the knowledge gains of teacher candidates with respect to the effective use of educational technology tools.

## **PURPOSE and RESEARCH QUESTIONS**

Effective application of TPACK requires pre-service teachers to transform those bodies of knowledge that are typically considered separately

into one distinct entity to produce meaningful teaching and learning (Mouza & Karchmer-Klein, 2013). This will lead to the development of integrated knowledge from diverse fields, including knowledge of student thinking and learning, subject matter, and technology (Koehler & Mishra, 2005; Koehler, Mishra, & Cain, 2013). However, research has shown that teachers generally cannot integrate TPACK in ways that produce meaningful learning with information and communications technology (Koh, 2013).

This study, therefore, aims to integrate the TPACK concept into teacher education using a case study teaching method for chemistry instruction. In the current study, pre-service teachers were asked to develop a lesson plan for the same chemistry subject that: (a) used macro, micro, and symbolic levels of chemistry; (b) connected the lesson to a daily life situation; (c) used multiple teaching methods based on case study teaching; (d) evaluated the effectiveness of the instruction; and (e) integrated educational technologies that help students to visualize the abstract nature of chemistry. The following research questions guided this study:

1. To what extent is TPACK development reflected in pre-service teachers' case-based lesson planning materials?
2. What are the pre-service teachers' perceptions on their development of TPACK after case-based lesson planning?

## **METHODOLOGY**

A qualitative study with action research approach was undertaken for planning, improvement, and configuration of a Special Instructional Methods Course in a Chemistry Education certificate program. A thematic content analysis was conducted of student-generated documents and responses to an open-ended survey, both of which made use of the TPACK framework.

### **Context**

The research team consisted of two faculty members (each holding a Ph.D. in science education). The first researcher engaged in study design, implementation, and the second researcher in reporting of the findings, while researchers took part in the analysis of the data. The research took place at an education faculty of a state university of the northwestern area of Turkey. Students were taught in a large classroom using basic technology, including a computer connected to a projector.



## **Participants**

In the present study, the TPACK framework was used in the training of chemistry pre-service teachers. Participants were selected using convenience sampling, with the sample being students enrolled in a chemistry teacher pedagogical certification program. The participants consisted of 21 pre-service teachers (16 females and 5 males). The participants were trained over a 21-weeks period during the spring and summer term of the 2015 academic year. The pre-service chemistry teachers were enrolled in an instructional methods course, an in-school practicum, instructional technologies and material development courses during the spring and summer term, which were all taught by one of the researchers. In the special instructional methods course, participants were introduced to teaching methods such as constructivist approaches, the 5E learning cycle, inquiry and discovery teaching, argumentation, concept mapping, multiple intelligence theory, and case study teaching methods. The in-school practicum course required the pre-service teachers to plan, revise, and teach chemistry lessons during their field practice in secondary schools. The instructional technologies course covers material design and development techniques, foundations of instructional design, smart board practices, and using ICT in chemistry instruction, among other topics. In the instructional technologies course, the first and second sections correspond to PK the third and fourth sections corresponds to TK of TPACK. Content Knowledge (CK) was not specifically taught in these courses as the pre-service teachers had already graduated from the science faculty having a bachelor's degree in chemistry. Therefore, they can be considered as subject matter experts to at least a basic level of chemistry content knowledge.

## **Data Collection Tools**

- **Lesson Plans**

Before the study, pre-service teachers developed five lesson plans including 5E, inquiry teaching and science process skills, multiple intelligence, and argumentation methods. They presented their lesson plans in class and feedback was given about lesson plans.

The primary data sources used in this study were participants' case-based lesson plans. Pre-service teachers developed their lesson plans either as an individual or as a team of two. Twelve data sets were collected. These data were used as indicators of the participants' TK, PK, CK, and TPACK development.

## • Open-Ended Responses

Qualitative data were collected by having participants respond to the following open-ended directive:

Please briefly discuss the contribution of your development of a case-based lesson plan using TPACK on your content, technology, and pedagogy knowledge.

### Process

For the purposes of the present study, the pre-service teachers were expected to plan and implement a lesson that incorporates ideas of TPACK by using a case study teaching method. Following the training sessions, the participants either as a team of two or individually were given two weeks to develop the assignment within the secondary school chemistry curriculum. During the planning phase, the pre-service teachers were in communication with the instructor to get feedback and suggestions for their instructional designs. Following the planning phase, pre-service teachers presented their plans to classmates and the instructor in the university class setting.

### Data Analysis

To analyze the participants' reflections on their development of TPACK, each lesson plan was analyzed using a content analysis method by the researcher and a subject matter expert collaboratively to increase inter-rater reliability. Chai, Koh, and Tsai (2013) have proposed an assessment method using TPACK to directly evaluate teachers' performance on a specific task to help determine the impact of interventions and professional development programs. For this purpose, each lesson plan was coded using a rubric that was developed by the researcher for assessing TPACK for meaningful chemistry learning with a case study teaching method. Koh (2013) stated that using rubrics for coding of lesson plans can lead to the combination of lesson activities within a discipline that illustrate meaningful learning. The rubric included six evaluation criteria: (a) using technology in instruction; (b) pedagogical knowledge (using instructional strategies); (c) accuracy of content; (d) using all levels of chemistry (micro, macro, and symbolic); (e) case-based teaching; and (f) evaluation methods. Each criterion was numbered from 1 to 4. While the number 1 indicated unsatisfactory, 4 shows full success in satisfying the criterion. The rubric is presented in Table 2.

**Table 2.** Rubric for Assessing TPACK for Meaningful Chemistry Learning with a Case-Based Teaching Method

<b>Dimension</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>
Technology	Does not use ICT tools or ICT tool use is not directly related to the subject matter or do not fit into the levels of chemistry	ICT tools help the students to understand only one of the macro, micro or symbolic levels of chemistry	ICT tools such as animations, simulations, videos, and smart boards help the students to understand the two of the macro, micro and symbolic levels of chemistry	ICT tools help the students to understand all of the micro, macro, and symbolic levels of chemistry
Pedagogy	Does not use teaching methods effectively	Uses case study teaching method, but not any other teaching methods	Able to use case study teaching method along with a different teaching method.	Able to use case study teaching method while also integrating several other methods
Content	Completely wrong	Partially true with some wrong content	Partially true but incomplete in some ways	Completely true
Levels chemistry	Does not integrate all the levels so that they relate to each other	Uses one level of chemistry	Integrates two levels of chemistry effectively	Integrates all three levels of chemistry effectively in terms of relating with each other
Case study	Case study not related to a daily life problem, although it consists of questions, and does not encourage the learners to investigate	Case study related a daily life problem, but does not consist of questions and does not encourage the learners to investigate	Case study related a daily life problem, but consists of a few questions and does not encourage the learners to investigate	Case study related a daily life problem, consists of enough questions and encourages the learners to investigate
Evaluation	The case does not include evaluation questions	The case includes multiple choice and open-ended type evaluation questions	The case includes evaluation questions with alternative measurement tools	The case consists of evaluation questions of learners that require responses with argumentation

## Trustworthiness

The data were independently evaluated by two raters using the identified categories to increase inter-coder reliability.

## RESULTS

### Research Question 1--Results of Pre-Service Chemistry Teachers Lesson Planning

Lesson plans were analyzed using the rubric in Table 2. According to this, the scores from each dimension vary between 1 and 4 and possible overall scores could range from 6 to 24. As can be seen in Table 3 two of the groups' scores are 22, one of them was 19, two of them were 18, two of them was 17, three of them were 16, one of them was 15, and one of them was 14. It can be said that most of the groups whose scores were above the average level ( $\bar{x}=17.50$ ,  $sd=2.53$ ) and that those pre-service teachers successfully developed a lesson plan using a case-based teaching method.

**Table 3.** Grading Scores of Each Lesson Plan

Lesson Plan	T	P	C	CL	CBT	E	S
The effects of plastics	4	3	4	4	3	4	22
Atom bomb	3	3	4	4	4	4	22
Hydroelectric power station	2	3	4	3	3	4	19
Nuclear energy	2	3	3	3	3	4	18
Lipids	3	3	4	3	3	2	18
Boiling and freezing point	3	3	4	3	2	2	17
Electroplating	3	3	4	3	2	2	17
Acids and bases	2	3	4	3	2	2	16
How air bags work	2	3	4	3	2	2	16
Combustion reaction of coal	2	3	4	2	3	2	16
Corrosion of iron	1	3	4	3	2	2	15
Glass Industry	2	2	4	2	2	2	14
Mean	2.41	2.91	3.91	3.00	2.58	2.66	17.50
SD	.80	.29	.29	.60	.66	.98	2.50

T: Technology; P: Pedagogy; C: Content; CL: Chemistry Level; CBT: Case-Based Teaching; E: Evaluation; S: Total Score of lesson plan

## **Technology Dimension**

The groups were asked to integrate technology by using animations, simulations, and/or videos for instruction in order to teach across the three levels of chemistry. Only one of the groups was to be able to integrate technology for macro, symbolic, and micro levels of chemistry. The participants gained the lowest mean score on the Technology dimension of the rubric ( $\bar{x}=2.41$ ,  $sd=.80$ ). While four of the groups found videos for macro and micro levels of chemistry, six of them used videos for only the macro level of chemistry. Only one of the groups did not integrate technology for their lesson plans. These results showed that the groups were not able to integrate instructional technologies in order to teach all three levels of chemistry at the same time. However, the majority of them used ICT for their lesson plans in some ways.

## **Pedagogy Dimension**

The groups' mean scores on the dimension were above the central level ( $\bar{x}=2.91$ ,  $sd=.29$ ). Most of them preferred to use the case study teaching method by integrating 5E learning cycle model. Only one group did not use any other teaching method in combination with a case-based teaching method.

The application of case-based teaching can be seen under the pedagogy dimension. The mean score for the groups was 2.83 with .60 standard deviation. Only one group was able to get the highest score on implementation of the method. Although, five groups' cases were about a daily life situation and encouraged the learners to investigate the questions, their questions were lower than the most successful group. The rest of the groups' cases only consisted of a few questions that did not promote investigation.

Similarly, the evaluation (E) dimension can also be seen as a part of the pedagogical element of the TPACK framework. The mean score for the Evaluation dimension was 2.66 ( $sd=.98$ ). Four groups integrated argumentation into the evaluation of the case-based lesson. Eight groups used open-ended questions with discussions on the dimension.

## **Content Dimension**

The content dimension had the highest mean scores ( $\bar{x}= 3.91$ ,  $sd=.29$ ) obtained by the learners, which was not surprising since they each already had a bachelor's degree in chemistry from a science faculty. Only one lesson plan's content, which was on nuclear energy, was seen as

including inadequate content knowledge. It might have included more information about fusion with chemical equations. Only two groups were able to integrate all three levels of chemistry in their lesson plans, eight groups used macro and micro levels, and one group used just the macro level of chemistry.

### **Research Question 2- Pre-service teachers' perceptions on their development of TPACK**

The second research question assessed the participants' perceptions about the development of TPACK through the qualitative analysis of the related an open-ended question. The responses were coded using themes that combined the elements of TPACK—TK, PK, CK, and TPACK. All of the participants answered the questions by considering all of the dimensions. Therefore, the teacher trainees' answers did not focus on a specific theme.

#### **Content**

Ten participants thought that lesson planning did not affect their content knowledge as they had already graduated from a science faculty. An illustrative statement was as follows:

*I think I have enough chemistry knowledge as a result of my four-year chemistry studies in university.*

Eleven participants stated that they developed their content knowledge. The following are example statements:

*...I do not think that I would have difficulties in teaching chemistry concepts. However, I learned the three levels of chemistry, and to use them at the same time for my instruction. This also improved my chemistry content knowledge.*

*...I can say that I learned better the chemistry topic about the glass industry by using a case-based lesson plan. Because chemistry has many abstract concepts, it is hard to relate it with daily life situations.*

*I was thinking that I do not have any missing chemistry knowledge on the secondary chemistry curricula. I realized that I have forgotten some topics. Because, I graduated 11 years ago....*

## **Pedagogy**

All of the learners thought that they developed their PK using case-based lesson planning. Their responses were generally about what they learned about teaching methods during the instruction. ***The illustrative statement is presented below.***

*I was using just lecture and problem solving methods in tutoring institutions. I now know many teaching methods and how I can use and combine them at the same time in my instructions ....*

## **Technology**

Similarly, all of the participants mentioned that they improved their TK after the implementation. However, only one talked about the TK. The majority of the statements were related to TCK as they generally stated that they learned which instructional technologies they can fit into the micro, macro, and symbolic levels of chemistry. Three participants expressed their ideas on TPACK development by saying they learned which educational technology was compatible with the chemistry concepts and the teaching methods. The following first example is illustrative of TK, the second is of TCK, and the third is of TPACK:

*I had limited technology knowledge before the lesson planning. I know the web sites, animation and simulation programs, and places for downloads that I need in order to find pictures, videos, animations, and simulations for specific chemistry subjects (TK).*

*Before this, I was thinking of using educational technologies as preparing PowerPoint presentations and watching videos. I learned how to use them, and in which stage of the course, and which can fit into the levels of chemistry (TCK).*

*This implementation has been effective for using educational technologies at the right stage of the lesson. I will use ICT along with experiments when teaching abstract concepts by using multiple teaching methods (TPACK).*

## **CONCLUSIONS and DISCUSSION**

This study examined the effects of case-based lesson planning on pre-service teachers' TPACK development in Instructional Technologies and Material Design course based on the TPACK framework (Mishra & Koehler, 2006). The students attended 21 weeks of courses within the context, pre-service chemistry teachers. The students were asked to develop a lesson plan for the same chemistry subject including macro, micro, and symbolic levels of chemistry, connecting the lesson to a daily life situation, using multiple teaching methods in combination with case study teaching, evaluating the effectiveness of the instruction, and integrating educational technologies that help students to visualize the abstract nature of chemistry. Then, the participants had to apply their lesson plans to high school students within the scope of school practicum. When evaluating their case-based lesson plans, it was found that their mean scores in order from highest to lowest were the content dimension, pedagogy, and technology, respectively. The content knowledge of learners was significantly higher than the pedagogy and technology knowledge. This finding is not unexpected because these prospective teachers received pedagogical and technology-related courses within the teaching certificate program following a 4-year undergraduate degree in chemistry. These findings are consistent with respect to past research, indicating the effectiveness of case-based teaching in students' understanding of chemistry concepts (Mouza & Klein-Karcmer, 2013). However, the participants achieved a good success with a score of 2.91 on the pedagogical dimension and 2.41 points on the technology dimension in 4 points. Contrary to the findings of our study Canbazoğlu Bilici et al. (2016) found that science teacher candidates had a relatively good amount of knowledge of the orientations toward teaching science. Science teacher candidates are not taking a one-year intensive program, but taking courses with teaching content during their 4-year undergraduate teacher education studies.

Joo, Park and Lim (2018) stated that TPACK will significantly affect the self-efficacy of a teacher in new learning technologies and media in learning settings. Karolcik and Cipkova (2017) pointed out that teachers are looking for these connections between technologies and methodologies for a suitable use of digital technologies in a particular curriculum topic in Chemistry of teaching process based on the TPACK framework. In this context, it is very important in teacher education to include more applications on how to integrate chemistry content with specific teaching methods and educational technologies in the teaching process.



These results were also consistent with the findings of the second research question. The pre-service teachers' perceptions on their development of TPACK after the implementation of the lesson planning assignment were overall positive in each dimension. They mostly thought the implementation had been effective mostly on their PK, TK, TCK, and TPACK developments when compared to CK.

Our results support Koehler, Mishra, and Cain's (2013) statement that the TPACK framework has offered many potential benefits for promoting research in teacher education, teacher professional development, and teachers' use of technology. On the other hand, it should be considered that TPACK-based professional development for teachers needs to be flexible as the teachers' TPACK is not limited to a particular approach to teaching, learning, or technology integration (Harris et al., 2009). Effective technology integration needs independent content, technological, and pedagogical knowledge (Harris & Hofer, 2011). Therefore, further research is needed in the area. Chai et al. (2013) stated that the TPACK framework still needs to be further understood and developed so that it can be put into practical use in ways that can guide teachers' design of ICT interventions. The results of this research provide evidence that teachers' continued development of knowledge within the TPACK framework will be beneficial, especially when integrating those dimensions with specific instructional methods that ensure that the content is related to daily life examples.

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