PRE-SERVICE TEACHERS' TECHNOLOGY INTEGRATION AND THEIR TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPCK)

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ABSTRACT: How technology is integrated to the lessons is important because what is meant by teachers' use of technology varies widely. Therefore, the purposes of this study were to determine pre-service physics teachers' TPCK and to examine their technology integration skills during their practices. Technological pedagogical content knowledge frames this research. The participants of the study were senior pre-service physics. In order to measure the participants' true knowledge, ability, and practice about TPCK, data were collected by using mixed-methods including observations, lesson plans, and interviews. Results of this study conclude that pre-service physics teachers can reflect technology integration to their practices more successfully than to their lesson plans. They can behave like an expert while using CBL technology in their teaching. Although they know how to use technology effectively, some of them need to improve their knowledge and realize that technology is not a vitamin whose mere presence catalyzes better educational outcomes. In addition, pre-service physics teachers have high level TPCK; hence, they have tendency to use technology and have a coherent knowledge about technology, pedagogy and content. This study suggests that various technologies should be introduced in teacher education programs and teacher candidates should use these technologies as tools to gain progress in advancing their TPCK.

Keywords: Pre-service teachers, TPCK, Technology integration.

INTRODUCTION

Technology has begun to take a crucial role in education; therefore, there has been substantial investment on technological tools in order to integrate technology to the science teaching. However, how technology is integrated to the lessons is important because what is meant by teachers' use of technology varies widely (Bebell, Russell & O'Dwyer, 2004). According to Inan and Lowther (2010), technology integration can be grouped into following three broad categories;

- Technology for instructional preparation,
- Technology for instructional delivery,
- Technology as a learning tool.

Teachers use technology for preparing instructional documents and some materials, or making lesson plans. When technology is used for instructional delivery, the students or teachers can use it during the class. Teachers may present instruction of the lecture through a projector or via power point presentation or students may use computer applications such as simulations or animations. The third category, technology as a tool, contains usage of basic software; such as Micro-Computer Based Laboratory (MBL) and Calculator Based Laboratory (CBL) (Inan & Lowther, 2010).

Teachers should have necessary training about technology usage. The lack of teachers' technology integration skills has an important effect on frequency usage of technological equipment in lessons (Palak, 2004). Besides, even though schools have enough technology, it is observed that these opportunities cannot support the improvement in science teaching (Lawther, Inan, Strahl & Ross, 2008). Therefore, the purposes of this study were to determine pre-service physics teachers' TPCK and to examine their technology integration skills during their practices.

THEORETICAL FRAMEWORK

Theories, frameworks, or models can be seen as conceptual lenses through which to view the world. Technological pedagogical content knowledge frames this research.

Using technology in learning process requires teacher competences in technology. To be successful, the new technologies call for the use of advanced pedagogies. Teachers should need to have a coherent knowledge about technology, pedagogy and content. Hence, the understanding of relationship between three components of knowledge is an important point in order to integrate technology to the lesson effectively. Technological Pedagogical Content Knowledge, known as TPCK or TPACK, has become theoretical framework of teacher knowledge for technology integration. TPCK framework allows us to make sense of the complex web of relationships that exist when teachers attempt to apply technology to the teaching of subject matter (Mishra & Koehler, 2006). In recent years, researchers described TPCK within Schulman's (1987, 1986) framework description of Pedagogical Content Knowledge (PCK). TPCK is an extension of PCK and is achieved when a teacher knows (Graham and others, 2004);

1) How technological tools transform pedagogical strategies and content representations for teaching particular topics,
2) How technology tools and representations impact a student's understanding of these topics.

According to Koehler and Mishra (2008), TPCK has three components: PCK, TPK (Technological Pedagogical Knowledge) and TCK (Technological Content Knowledge). PCK is the connection and relation of pedagogy and content knowledge. TPK represents the integration of technology with general pedagogical strategies. It is related to engage students with technology effectively in the learning process. TCK represents knowledge of technological tools that are used by teachers within content. Consequently, TPCK, that is center of the model, represents the usage of technology to provide content and pedagogical strategies (see Figure 1).

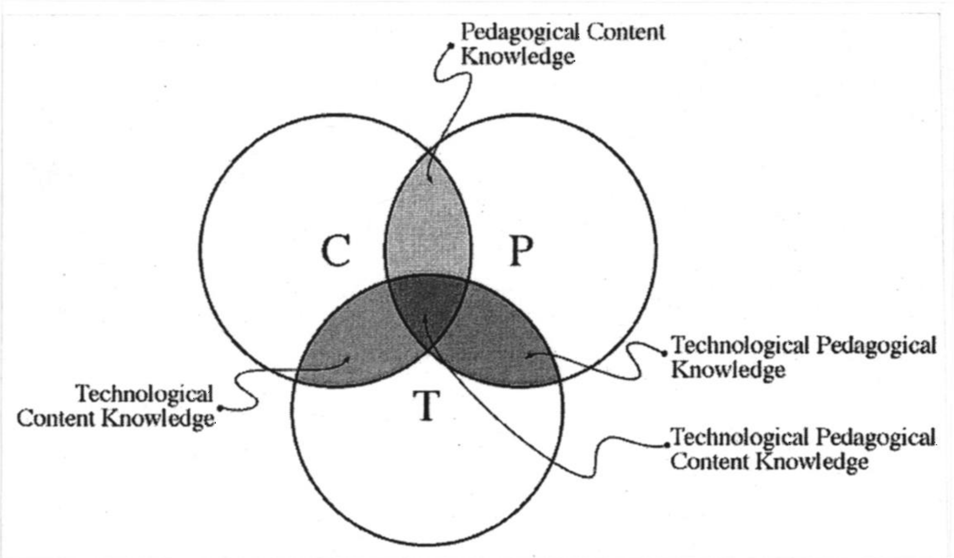

Figure 1. Koehler and Mishra's (2008) components of Technological Pedagogical Content Knowledge

TPCK approach is not completely new. Knowledge about technology cannot be treated as context-free and that good teaching requires an understanding of how technology relates to the pedagogy and content (Alayyar, Fisser and Voogt, 2012).

LITERATURE REVIEW ON TPCK AND TECHNOLOGY INTEGRATION

Teachers must not focus on the technology itself, but rather on the learning outcome that is supported by technology (Millen, 2015). Teachers' knowledge to integrate content, pedagogy and technology has become important. As a result, a quite number of studies have been focused on to examine how teachers and teacher candidates integrate technology into their teaching and to determine their TPCK.

For example, Archambault and Crippen (2009) performed a study which examined a national sample of 596 K-12 online teachers and measures their knowledge with respect to three key domains as described by the TPCK framework: technology, pedagogy, content, and the combination of each of these areas. Findings indicated that knowledge ratings were the highest among the domains of pedagogy, content, and pedagogical content, indicating that responding online teachers felt very good about their knowledge related to these domains and were less confident when it came to technology (Archambault & Crippen, 2009).

Forssell (2011) explored the relationship of accomplished teachers' TPCK confidence to their use of technology with students and to their teaching and learning contexts. The analyses focused on the responses to an online survey by 307 teachers. Analyses showed that these accomplished teachers' confidence in their knowledge of how to use new technologies for teaching was different from their confidence in using technologies more generally. Further, TPCK confidence related to student use of computers in the classroom (Forssell, 2011).

Jang and Tsai (2013) explored TPCK of 1210 secondary school science teachers using a new contextualized TPCK model. The results indicated that experienced science teachers tended to rate their content knowledge and pedagogical content knowledge in context (PCKCx) significantly higher than did novice science teachers. However, science teachers with less teaching experience tended to rate their technology knowledge and technological content knowledge in context (TPCKCx) significantly higher than did teachers with more teaching experience (Jang & Tsai, 2013).

Liang, Chai, Koh, Yang and Tsai (2013) applied TPCK survey to explore 366 Taiwanese in-service preschool teachers' technological pedagogical content knowledge. The correlation analyses revealed that more senior preschool teachers might show a certain degree of resistance toward technology-integrated teaching environments and also preschool teachers with higher education qualifications tended to have more knowledge of technology use and ICT integration in their teaching environment namely in the TK and TPCK scales. The scores of the university graduates were significantly higher than those with lower qualifications. The preschool teachers' age was negatively related to the TK and TPCK scales therefore older teachers need continuous professional development activities to help them grow with the advancements of technology (Liang, Chai, Koh, Yang, & Tsai, 2013).

Due to the fact that self-report instruments were used to discover teachers' TPCK in the studies mentioned above, the results might not reflect what TPCK these teachers actually would perform during their practices.

Because confidence in TPCK is different from confidence in using technology more generally, it is important to create opportunities for teachers to learn how new technologies support their specific goals in the grade, subject area, and school context in which they teach (Forssell, 2011). Therefore, Mudzimiri (2012) studied the development of connections between technology, content and pedagogy by using three courses that are offered in collaboration. Five pre-service teachers participated in the research data gathered by TPCK survey, teaching philosophy statements, lesson plans, student teaching episodes, and weekly instructor meeting notes. Results of the study showed that the development of TPCK in pre-service teachers was not the same as the development of TPCK in in-service teachers. Furthermore, there was a mismatch between the enacted TPCK and the self-reported TPCK of the participants. For each participant, the self-reported TPCK scores were higher than enacted and observed TPCK behaviors. Results of this study suggested that TPCK could be influenced by the grade level or type of curriculum and whether the lessons were developed by a group of teachers or by individual teachers (Mudzimiri, 2012).

In a study performed with 82 graduate teacher education students to investigate their knowledge and practice of teaching with technology as well as how that knowledge and practice changes after participation in an educational technology course, significant gains in reported and demonstrated TPCK constructs were found by using mix-methods (Sabo, 2013).

Lowder (2013) developed a teacher education course to support the growth of TPCK among pre-service teachers within a science methods course. The impact of the course and how it might be improved for future semesters were evaluated by doing action research. The course included nine females between the ages of 18 and 34 years old. TPCK surveys, learning activities, and an assessment rubric were used and pre-service teachers were introduced to the TPCK framework in an effort to guide their lesson plan development. The teaching strategies and learning activities that supported TPCK development among the pre-service teachers in the course included assigned readings, videos, specific content resources, scaffolding of class activities, and the introduction of the TPCK lesson plan format. Results showed that the students' TPCK knowledge increased in key TPCK areas (Lowder, 2013).

In a design-based research project, Koh and Divaharan (2013) implemented an instructional process to facilitate pre-service teachers' TPCK development as they learn to integrate information and communication technology (ICT), specifically interactive whiteboard (IWB), in their teaching content subjects. The courses provided them with opportunities to explore the pedagogical uses of ICT tools. The findings revealed that strategies such as tutor modelling and hands-on exploration of ICT tools appeared to be more advantageous for fostering technological knowledge and technological pedagogical knowledge (Koh & Divaharan, 2013).

Some research investigated teachers' technology integration. For instance, Inan and Lowther (2010) pointed out the direct and indirect effects of 1382 teachers' individual characteristics and perceptions of environmental factors that influence their technology integration into classrooms. They presented that teachers' demographic characteristics such as years of teaching and age affect their computer proficiency. Teachers' demographic characteristics negatively and teachers' computer proficiency positively affected their technology integration. Furthermore, teachers' beliefs and readiness and school-level factors such as availability of computers and technical support positively influenced teachers' technology integration. Moreover, teachers' beliefs and readiness mediated the indirect effects of school and teacher level factors on teachers' technology integration (Inan & Lowther, 2010).

In a case study research done by Stoilescu (2011), three teachers over 10 years of experience in teaching mathematics in secondary schools at an urban public school were observed in their classrooms and interviewed about their experiences of teaching mathematics and integrating computer technology in their day-to-day activities. Although teachers displayed a high degree of integration of technology, they had difficulties in purchasing and maintaining the computer equipment. They had some difficulties in trying to integrate new technologies as these required time, preparation, and dedication (Stoilescu, 2011).

The review of research on TPCK suggests that more research is needed to explore how science teachers integrate specific technology in their teaching practices by collecting data from various methods including observing and interviewing.

PURPOSES OF THE STUDY

Assessing TPCK requires focus on a specific technology using in a particular context and in support of a clear set of curricular objectives, and it will require some measure of teachers' PCK as well (Forssell, 2011). Thus, the research questions put a light on this study are as follows:

1. What is pre-service physics teachers' technological pedagogical content knowledge?
2. How do pre-service physics teachers integrate calculator-based laboratory (CBL) technology into their practices?

METHODOLOGY

Case study design (Stake, 1995) was guided to the research. The participants of the study were 10 senior pre-service physics teachers, three of whom were male. In the previous semester, they had learned the fundamental learning and teaching theories related to physics education in K-12 settings through readings, explicit teaching and activities, and they had designed and implemented a lesson plan based on the constructivist philosophy. Science teachers could develop their TPCK through using technological tools in science teaching (Jang & Tsai, 2013). Therefore, the participants enrolled in a course titled as "Technology Integration in Physics Teaching". One of the researchers was the instructor of the course. Since teaching with technology requires complex skills and understandings, the participants had opportunity to learn and integrate Calculator-Based Laboratory (CBL) technology into teaching of various physics subjects in this course. Then, they again designed and implemented a lesson plan about the same physics concepts they got prepared in the previous semester. However, this time they were required to use the CBL technology in their practices. The CBL system is a portable, handheld, battery-operated data collection device for gathering real-world data with the help of sensors. Data collected with a CBL device can be retrieved and analyzed by graphing calculators. Before starting to implementation, the participants' CBL knowledge and skills were measured to make sure that all the participants learned this technology. The participants were given a list consisting of the physics concepts measured by using CBL sensors and they chose the concept they would teach from the list. Pseudonyms names of the participants and the concepts are presented in Table 1.

According to Forssell (2011), surveys have limitation because they involve the reference points used by respondents to rate their own knowledge. Consequently, the degree to which teachers agree with statements in the TPCK confidence scale may depend on their perception of the abilities of others. Interviews and observations may allow us to surface evidence of pedagogical content knowledge, and to understand how teachers see the relationship between technology and PCK (Forssell, 2011). On the other hand, lesson plans scored with a rubric are a suitable proxy for teacher practice, but do not replace observations of teacher behavior in the classroom (Sabo, 2013). For that reason, in order to measure the participants' true knowledge, ability, and practice about TPCK, data were collected by using mixed-methods including observations, lesson plans, and interviews.

Table 1. Participants and The Concepts They Thought

Name of the participant	Concepts
P-1	Heat and temperature
P-2	Polarization of light
P-3	Waves
P-4	Alternative current
P-5	Energy
P-6	Momentum and collisions
P-7	Motion in an inclined plane
P-8	Colors
P-9	Capacitor
P-10	Spring pendulum

The pre-service physics teachers' skills while they were integrating the CBL technology into their teaching were observed by two researchers. Science Classroom Observation Rubric (SCOR) developed by Burry-Stock and Oxford (1994) was filled out by the researchers separately for each participant. A constructivist, student-centered perspectives underlies SCOR. The four categories that form the SCOR are facilitating the learning process with the help of constructivist approach, content specific pedagogy, contextual knowledge, and content knowledge. The rubric is based on the following 18 criteria each has a rating score from 1 to 5:

- Teacher as a facilitator (C1)
- Engagement of students to the activities in classroom (C2)
- Attending of the students to the experiences (C3)
- Innovation (C4)
- Frequency of textbook usage (C5)
- Conceptual understanding of students (C6)
- Interest of students to the lesson (C7)
- Variability of teaching methods (C8)
- The capability of the students' high-level understandings (C9)
- The integration of content and process skills (C10)
- The relationship between concepts and evidence (C11)
- Dissolution of misconceptions (C12)
- The relationship between teacher and students (C13)
- The change in teaching methods in order to facilitate understanding (C14)
- The usage of model and metaphor (C15)
- The consistency of lesson (C16)
- The balance of depth and content of lesson (C17)
- Accuracy of content (C18).

Another data source was the pre-service physics teachers' lesson plans they prepared in detail. Moreover, interviews were conducted with the participants just after their practices to understand their thoughts about technology integration and to evaluate their practices. They were asked how they integrated the CBL technology in their practices, what else they would have done during their practices, how they preferred to use technology in their teaching, and what they could do to provide students for reaching and producing knowledge while using technology. The interviews were done in the researcher's office and lasted 10-15 minutes.

The highest score one can get from SCOR is 90. Mean values of SCOR's scores given by two researchers were calculated for each criterion. Internal consistency computed by Cronbach's Alpha formula was high, with reliability coefficient of .91. The researchers of this study compared their scores and were able to reach 92% agreement. The reliability measured by Cohen's κ was .80. There seems to be general agreement that Cohen's κ value should be at least 0.60 or 0.70 (Wood, 2007). Consequently, the coding done for the participants' skills had adequate reliability. Five-point scoring rubric was created by the researchers to analyze the participants' lesson plans. Some of the items in the rubric are:

- Identification of lesson objectives correctly,
- Determination of appropriate technology for the purpose of the lesson,
- Integration of technology in accordance with constructivist approach,
- Specifically writing of the questions asked during the lesson and their answers.
- Having Plan B in case of any technology inconveniency.

One more five-point rubric was generated to analyze transcripts gathered from the interviews. The rationale behind the rubric was integrating and using technology as a tool consistently with the constructivist approach. The following items can be given as examples from the rubric:

- Technology is a tool for learning by doing hands on science,
- Technology is used to provide students for showing their understanding,
- Technology is used to increase students' thinking by providing social constructivist environment,
- Technology is a tool to help students construct hypothesis,
- Technology is used to help students give scientific explanations.

The pre-service physics teachers' TPCK was determined by calculating the mean of the mean values of their scores collected from the five-point rubrics used for SCOR, lesson plans, and interviews and labeled based on the differentiation given in Table 2.

Table 2. Categories for The Participants' TPCK Based on The Mean Values

Mean	Category
1 - 2	Needs improvement
2,01 - 3	Medium
3,01 - 4	Good
4,01 - 5	Sophisticated

RESULTS AND DISCUSSION

Table 3 shows the mean scores of the pre-service teachers' teaching practices given by two researchers while they were using technology. The columns in the table illustrate the criteria of SCOR. High scores represent that the pre-service physics teachers could integrate the CBL technology in their practices successfully. Relationship between teacher and students (C13) was the skill that all the participants got the highest score. This skill was under the contextual knowledge category. The teacher candidates established a good relationship with their students and did not make any discrimination among them. All the participants, apart from P-3, were accomplished the Criterion 5, frequency of textbook usage (C5). That is, the pre-service physics teachers' practices did not depend on textbooks and they prepared their materials and worksheets by considering the students' needs. The reason for this finding is that CBL applications were not part of the curriculum and the participants had to become creative in their preparations. Criterion 5 was under the category of facilitating the learning process with the help of constructivist approach. On the other hand, the participants got the lowest scores in the criteria of dissolution of misconceptions (C12) and change in teaching methods in order to facilitate understanding (C14), both of whom were under the category of contextual knowledge. Their scores in these skills were good but not sophisticated. When students' misconceptions came out, the teacher candidates could almost resolve them by promoting discussions among the students and encouraging to collect evidence. Additionally, the pre-service teachers were generally aware of students' understanding and made changes in their practices if it was necessary.

Table 3. Mean Scores of The Pre-Service Teachers' Teaching Practices

	Criteria of SCOR																	
P	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**	**C17**	**C18**
P-1	4	4	5	5	5	4	5	4	4	4	3	4	5	3	5	4	4	4
P-2	3	4	4	3	5	3	3	3	3	4	3	3	5	4	4	4	4	4
P-3	4	3	4	4	4	4	4	4	4	5	4	3	5	3	4	4	3	4
P-4	4	4	4	5	5	4	5	5	3	5	5	3	5	3	5	4	5	5
P-5	4	4	5	4	5	4	5	4	5	5	5	4	5	4	4	4	5	5
P-6	5	4	5	5	5	5	5	5	4	5	5	4	5	5	5	5	5	5

P-7	4	4	5	4	5	4	3	3	3	4	4	3	5	3	3	4	5	4
P-8	4	2	5	3	5	4	3	4	4	5	4	3	5	3	5	4	5	5
P-9	5	5	5	5	5	5	5	5	4	5	5	4	5	4	5	5	5	5
P-10	4	4	4	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5

To sum, role of the teacher was facilitator by providing students more active participation in the learning process and the class environment was suitable with student-centered teaching when the CBL technology was integrated into the lesson. These results were similar with the result revealed by Wetzel (2001), who found that technology had positive influence on pre-service teachers' practices positively.

Table 4 demonstrates the participants' TPCK levels and their levels in knowledge about technology integration, lesson plans, and technology integration skills. According to the table, a half of the participants sophisticatedly knew how to use technology as a tool in the constructivist approach. However, P-6 and P-9 needed to improve their knowledge in this issue. P-6 could not distinct the difference between using technology according to student-center strategies and teacher-centered strategies. P-9 thought that if there was technology in the instruction in one way or other, the instruction was already congruent with constructivism. 70% of the participants prepared either good or sophisticated lesson plans. Some of them had difficulties in reflecting technology integration to their lesson plans. They could allocate the time necessary for the activities. Nevertheless, they neither considered time loss due to technology settings nor paid attention to the time spent for student applications with CBL. Moreover, a few of them (P-5, P-5, and P-7) did not specified any teaching methods and did not mention how to assess students.

Except for P-7's practice, all the participants' teaching skills were sophisticated while using technology. The participants made demos by themselves before real application of the CBL technology with the students. They started their practices with a short summary of what they would do, following that they divided the students into groups and distributed the worksheets. Then, they encouraged the students to work in groups, collect data and reach conclusions. Sometimes they demonstrated the experiments to the students if it was necessary. The pre-service physics teachers could provide active student participation by using the CBL technology, facilitate learning, apply content specific pedagogy and have both contextual and content knowledge. The reason of the participants' sophisticated skills might be their familiarity with laboratory experiments because they used the CBL technology to do experiments.

Table 4. The Participants' TPCK Levels and Their Levels in Knowledge About Technology Integration, Lesson Plans, And Technology Integration Skills.

Participants	Knowledge about Integration of Technology	Lesson Plan	Technology Integration Skills	TPCK
P-1	Sophisticated	Good	Sophisticated	Sophisticated
P-2	Medium	Good	Sophisticated	Good
P-3	Sophisticated	Sophisticated	Sophisticated	Sophisticated
P-4	Sophisticated	Good	Sophisticated	Sophisticated
P-5	Sophisticated	Medium	Sophisticated	Good
P-6	Needs improvement	Medium	Sophisticated	Medium
P-7	Medium	Medium	Good	Medium
P-8	Good	Sophisticated	Sophisticated	Sophisticated
P-9	Needs improvement	Good	Sophisticated	Good
P-10	Sophisticated	Good	Sophisticated	Sophisticated

While a half of the participants had sophisticated TPCK, 30 % of the participants' TPCK had in good level. These high levels illustrate that the pre-service physics teachers had tendency to use technology and did not struggle to integrate technology into their practices. While they were using technology, they felt sure of themselves and had self-efficacy. Therefore, they could promote constructivist learning environment. Teachers having sophisticated TPCK choose and apply student centered teaching strategies (Niess, 2005) and explore a greater breadth of activities related to 21st century skills with their students (Forssell, 2011). Archambault and Crippen (2009) and Tokmak, Yelken and Konokman (2012) also revealed high TPCK among teachers in their studies.

TPCK is a dynamic concept. Context influences both teacher knowledge and practice, teacher knowledge influences practice, and practice influences which types of knowledge are used more in the classroom (Doering, Miller, Scharber, & Veletsianos, 2009). Moreover, the knowledge needed to effectively use technology to support student learning varies greatly depending on the students' developmental stage, the subject and topic being taught, and the technological tool being used (Forssell, 2011). Therefore, the results of this study may not be obtained if different technology is used and the participants teach different concepts.

CONCLUSIONS AND SUGGESTIONS

Teachers must not focus on the technology itself, but rather on the learning outcome that is supported by technology (Millen & Gable, 2016). Students' learning may depend on teachers' TPCK. Accordingly, this study explored pre-service teachers' TPCK. Research suggests that disappointing outcomes are frequently associated with lack of the necessary teachers' skills to integrate technology into their classes (Russell, Bebell, & O'Dwyer, 2003; Van Braak, 2001). By taking this suggestion into account, pre-service teachers' technology integration was also examined in this research.

Results of this study conclude that pre-service physics teachers can reflect technology integration to their practices more successfully than to their lesson plans. They can behave like an expert while using CBL technology in their teaching. Although they know how to use technology effectively, some of them need to improve their knowledge and realize that technology is not a 'vitamin' whose mere presence catalyzes better educational outcomes (Dede, 2001). In addition, pre-service physics teachers have high level TPCK; hence, they have tendency to use technology and have a coherent knowledge about technology, pedagogy and content.

Using technology might stimulate teachers' confidence and self-efficacy, so that they become more successful in their teaching. Future research must expand on this possibility.

There is no single technological solution that applies for every teacher, every course, or every view of teaching (Koehler & Mishra, 2008). The technology used in this study was limited with calculator-based laboratory (CBL). This study suggests that various technologies should be introduced in teacher education programs and teacher candidates should use these technologies as tools to gain progress in advancing their TPCK.

The current study contributes to the field by examining pre-service physics teachers' CBL technology usage in their teaching practices.

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