Pre-Service Teachers' Technological Pedagogical Content Knowledge (TPCK) Related to Calculator-Based Laboratory and Contextual Factors Influencing Their TPCK

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Abstract

The purposes of this study were to determine pre-service physics teachers' TPCK related to Calculator-Based Laboratory and to examine influences of some contextual factors on their TPCK. This research was based on the transformative model of TPCK that conceptualizes TPCK as a unique body of knowledge. Multiple case study design was used. Both qualitative and quantitative research methods were implemented to collect data. Correlations between TPCK and contextual factors were calculated to seek statistical relationships. The participants of the study were senior pre-service physics teachers. Their knowledge, ability, and practice of TPCK were measured by using various methods including observations, lesson plans, and interviews. More data were collected associated with the participants teaching philosophies and their attitudes towards CBL technology by using individual interviews, reflective journals, and surveys to focus on context related factors. Results of this study conclude that pre-service physics teachers can reflect CBL technology integration skills into their practices more successfully than to their lesson plans. They can behave like an expert while using CBL technology in their teaching. In addition, pre-service physics teachers have high level TPCK related to CBL; hence, they have tendency to use CBL technology as a learning tool and have a coherent knowledge about this technology, pedagogy and content. This study also concludes that instructional philosophy and awareness of CBL technology usage have significant impacts on their TPCK related to CBL. Having student-centered instructional philosophy and awareness of the specific technology integrated into instruction would contribute performing sophisticated TPCK.

Keywords: TPCK, CBL, pre-service teachers, physics

1. Introduction

Technology has become part and parcel of the everyday life of the citizens of this era such that today's societies rely heavily on technology with technological advances modifying how society and individuals behave (Hixon & Buckenmeyer, 2009). Furthermore, technology can enhance both the investigative and practical aspects of teaching (Osborne & Hennessy, 2003). Since teachers' pedagogy determines the quality and impact of the creation, implementation and subsequent use of technology (Ferdig, 2006), professional development should model and include the use of current and emerging technology resources as a mean to engage teachers (Annetta et al., 2013). Although there have been many efforts over the years in preparing teachers in the educational uses of technology, teachers still lack the skills and knowledge needed to be able to teach with technology successfully (Koehler, Mishra, & Yahya, 2007). This research focused on how pre-service teachers taught with technology and factors affecting their teaching.

Calculator-Based Laboratory (CBL) is a technological tool that allows immediate real-time data collection through the use of compatible probes and sensors. This tool also provides graphical representations of data gathered by students using a computer or graphing calculator (Lapp & Cyrus, 2000). CBL offers a powerful learning environment by permitting students to use advanced technologies to solve problems and do real science (Hale, 2000).

This technology enables students to collect data in a matter of minutes, rather than taking up the entire class period to complete an exercise (Kreuger & Rawls, 1998). Studies presented that embedding CBL into teaching enhanced students' and teacher candidates' understanding of mathematics and science concepts (Calik et al., 2014; Ersoy, 2004; Onur, 2008; Pilipezuk, 2006; Tajuddin, Tarmizi, Konting & Ali, 2009) and graphing ability (Kwon, 2002), improved their level of meta-cognitive awareness (Tarmizi et al., 2009), and affected their attitudes toward mathematics and science positively (Calik et al., 2014; Onur, 2008). Today, the most used technology for STEM education is calculator-based laboratory (Ebenezer, Kaya & Kassab, 2018). Therefore, it is important to examine pre-service science teachers' technological pedagogical content knowledge related to calculator-based laboratory.

2. Theoretical Framework

When teachers use technology to support student learning, they rely on a special kind of technology knowledge grounded in teaching (Forssell, 2011). 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 to integrate technology to the lesson effectively. This knowledge is called Technological Pedagogical Content Knowledge (TPCK or TPACK). TPCK is an extension of Pedagogical Content Knowledge (PCK), which is the synthesis of all knowledge required for effective teaching (Gess-Newsome, 1999). TPCK encompasses knowledge of: how different concepts can be represented using technologies, pedagogical techniques that employ technologies to teach content, what makes concepts difficult or easy to learn, students' prior understanding and skill set, and how technology can help redress some of the problems that students face (Khan, 2011).

This research was based on the transformative model of TPCK proposed by Angeli and Valanides (2005) that conceptualizes TPCK as a unique body of knowledge. In the transformative model, content, pedagogy, learners, technology, and context are regarded as significant contributors to the development of TPCK. The process of designing technology-enhanced learning is influenced by certain contextual factors, such as teachers' beliefs about how students learn, teachers' practical experiences about what can and what cannot work in a real classroom, teachers' views about the role of technology in teaching and learning, teachers' adopted instructional practices, school's vision, and educational goals (Angeli & Valanides, 2013). Therefore, in this study, pre-service teachers' TPCK and some contextual factors affecting their TPCK were examined.

3. Literature Review on TPCK

3.1 Research Related to Assessment of TPCK

Teachers must not emphasis the technology itself, but rather on the learning outcome that is supported by technology (Millen, 2015). As a result, a quite number of studies have been dedicated to determine teachers' and teacher candidates' TPCK. For example, Baser, Kopchac Ozden (2016) developed and validated a self-assessment survey that examined technological pedagogical content knowledge (TPCK) among preservice teachers learning to teach English as a foreign language. Archambault and Crippen (2009) performed a study which surveyed a national sample of 596 K-12 online teachers and assessed their knowledge with respect to 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). Lee and Tsai (2010) assessed teachers perceived self-efficacy in terms of their TPCK-Web. The participants were 558 teachers from elementary school to high school level in Taiwan. They found that older and more experienced teachers were found to have lower levels of self-efficacy, though teachers with more experience of using the web (including for instruction) had higher levels of self-efficacy. Koh, Chai and Tsai (2010) surveyed 1185 Singaporean pre-service teachers in terms of their TPCK. They noticed some differences in the participants TPCK perceptions by gender; however, the influence of age and teaching level were not strong. Forssell (2011) explored the relationship of accomplished teachers TPCK confidence to their use of technology with students and to their teaching and learning contexts. Analyses of the responses to an online survey by 307 teachers showed that these teachers' confidence in their knowledge of how to use new technologies for teaching was different from their confidence in using technologies more generally (Forssell, 2011). Jang and Tsai (2013) explored TPCK of 1210 secondary school science teachers using a new contextualized TPCK model. The results demonstrated 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 et al., (2013) applied TPCK survey to explore 366 Taiwanese in-service preschool teachers' technological pedagogical content knowledge. The correlation analyses revealed that senior preschool teachers showed a certain degree of resistance toward technology-integrated teaching environments and preschool teachers with higher education qualifications had more knowledge of technology use in their teaching (Liang et al., 2013). These studies revealed that teachers' TPCK related with their demographics and less experienced teachers had more confident in using technology in their classes.

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. More research focusing on observing teachers' TPCK are needed to truly determine how they use technology in their teaching. 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 with five pre-service teachers by gathering data from TPCK survey, teaching philosophy statements, lesson plans, student teaching episodes, and weekly instructor meeting notes. Results of the study showed that 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 (Mudzimiri, 2012).

3.2 Research Related to Development of TPCK

Some research studies aimed to improve pre-service teachers' TPCK by designing courses. For instance, Sabo (2013) explored 82 graduate teacher education students' knowledge and practice of teaching with technology and how that knowledge and practice changed after participation in an educational technology course. Significant gains were reported and TPCK constructs were found by using mix-methods (Sabo, 2013). Lowder (2013) developed a teacher education course to support the growth of TPCK among nine female pre-service teachers within a science methods course. TPCK surveys, learning activities, and an assessment rubric were used. Results showed that the teaching strategies and learning activities including specific content resources, scaffolding of class activities, and the introduction of the TPCK lesson plan format increased the students' TPCK knowledge (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) in their teaching content subjects. 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). Such efforts should continue to develop teacher education courses to facilitate construction of pre-service teachers' TPCK and to assess their TPCK while they are implementing technology into their lessons.

4. Purposes of the Study

Science pre-service teachers must develop an overarching conception of their subject matter with respect to technology and what it means to teach with technology to make technology an integral component or tool for learning (Niess, 2005). Hence, they must be given opportunities to develop appropriate and context-specific strategies for integrating the use of technology into their teaching practices (Mishra & Koehler, 2006). Findings show that pre-service teachers' active involvement in technology-enhanced courses is the major strategy to develop their TPCK and to improve their future teaching of subjects (Yigit, 2014). As a result, in this study, pre-service teachers were trained to understand how Calculator-Based Laboratory (CBL) technology can be integrated into physics teaching and learning and their TPCK was examined. Since technological skills alone are not enough to effective use of technology in teaching (So & Kim, 2009), some factors were taken under scope if they affected the preservice teachers' TPCK. The research questions of this research were as follows:

- What are pre-service physics teachers' technological pedagogical content knowledge (TPCK) related to calculator-based laboratory (CBL)?
- Which contextual factors do have influence on pre-service physics teachers' TPCK related to CBL?

5. Methodology

Multiple case study design (Yin, 2009) was used in this research. Both qualitative and quantitative research methods were implemented to collect data. Correlations between TPCK and contextual factors were calculated to seek statistical relationships.

5.1 Participants

The participants of the study were 10 senior pre-service physics teachers, three of whom were male. They were students in a physics teacher education program in a state university. The mean of their age was 22.5. Pseudonyms names (Sally, Orlando, Naomi, Debra, Elise, Daphne, Vick, Zara, Sawyer, and Nancy) were used to preserve anonymity. They were all volunteers to be part of the research and willing to meet with new technology. In the previous semester, they were taught fundamental teaching and learning theories related to physics education through readings, activities, and explicit teaching. They also had designed and implemented a lesson plan based on the constructivist philosophy. Some demographic information related to the participants is as follows:

Sally was 22 years old. She loved physics and enjoyed her physics classes when she was at high school. That is why she chose studying physics teaching in the university. She had been a tutor for one semester. Sally had not much involved with instructional technology before and started using it at the college.

Orlando was 23 years old. He found physics classes very dull and boring when he was a high school student because they were based on lecture and rote learning. He enjoyed reading scientific magazines. Although he loved technology in his life, he had struggle to reach the latest technology time to time because of financial issues.

Naomi was 23 years old, too. She argued that both her physics teachers in the high school and her professors in the college taught physics by implementing traditional methods and made her learn physics without comprehending. Her past experience with instructional technology was little.

Debra was 22 years old. She loved physics when she was in high school. Due to the fact that she was very fond of physics, she asked questions and did research about her questions. She started using instructional technology in high school.

Elise was also 22 years old. She liked physics even though she did not like her teacher’s teaching during high school. She learned physics by studying physics formulas. Her experiences with instructional technology had started in high school but in a very limited time.

Daphne was 23 years old. She believed that she learned physics by herself because her teachers had taught physics by lecture. She did not like them because of that. Due to her limited budget, she could not much use the latest technology in her life.

Vick was 23 years old, too. He started to like physics in high school. He learned physics by solving problems. He got bored when teachers tried to teach physics without inquiring. He believed that each physics subject should be taught by applying different teaching method. He became familiar with instructional technology when he was in a high school.

Zara was 22 years old. She thought that she could not get good physics instruction because she passed her classes just by studying midterms and finals. She supposed that using instructional technology was necessary in teaching physics but it should be supported with lecture. She used instructional technology in her lab sessions at the college.

Sawyer was also 22 years old. He did not like physics during his high school years. He enjoyed physics at the college due to the lab sessions where he thought he learned physics. He emphasized the importance of discovery and argumentation to learn physics. He started using instructional technology in his high school classes.

Nancy was 23 years old. She did not find herself successful at her science classes in the middle school; however, she enjoyed physics at the high school. She did not deal with instructional technology until college classes.

5.2 Instructional Context

Science teachers could develop their TPCK through using technological tools in science teaching classes (Jang & Tsai, 2013). Therefore, the participants enrolled in a course titled as “Technology Integration in Physics Teaching”, which was designed to offer pre-service physics teachers for investigating, thinking, planning, practicing, and reflecting (Niess, 2005). 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 CBL technology into teaching of various physics subjects in this course.

The participants designed and implemented a lesson plan for teaching the same physics concepts that they had taught in their micro-teaching practices in the previous semester. However, this time they were required to integrate the CBL technology in their practices. The reason for using the same physics concepts was to provide an opportunity to the pre-service teachers for focusing on integration of CBL technology instead on worrying about adequacy of their physics knowledge. In the first four weeks of the semester, the participants learned the CBL technology, prepared their experiments by considering the semi guided inquiry, generated their worksheets, and tried to obtain right graphics by using the sensors. Each week one pre-service physics teacher performed his/her teaching and the rest of the pre-service teachers took the role as students in ten-week duration. Both peer assessment and self-assessment were used for their practices. The participants kept reflective journals in this 14-week duration. The name of the participants and the physics concepts they taught are presented in Table 1.

Table 1. Participants and the Physics Concepts They Thought

Name of the participant	Concepts
Sally	Heat and temperature
Orlando	Polarization of light
Naomi	Waves and Sound
Debra	Alternative current
Elise	Energy
Daphne	Momentum and collisions
Vick	Motion in an inclined plane
Zara	Colors
Sawyer	Capacitor
Nancy	Spring pendulum

5.3 Data Collection

5.3.1 TPCK

According to Forssell (2011), surveys have limitation because they involve the reference points used by respondents to rate their own knowledge. 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). Additionally, 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 these reasons, data were gathered by using various methods including observations, documents (lesson plans), and interviews to measure the participants' true knowledge, ability, and practice of TPCK.

The pre-service physics teachers' practices while they were implementing CBL technology were observed by two researchers. The Expert Science Teaching Educational Evaluation Model - Science Classroom Observation Rubric (ESTEEM-SCOR) developed by Burry-Stock (1993) and revised by Varrella (1997) was filled out by the researchers separately for each participant. Constructivist epistemology underlies the SCOR. The following four categories including 18 criteria constituted this rubric: 1) Facilitating the learning process from a constructivist perspective (teacher as a facilitator, student engagement in activities, student engagement in experiences, novelty, textbook dependency), 2) Content-specific pedagogy (student conceptual understanding, student relevance, variation of teaching methods, higher order thinking skills, integration of content and process, connection of concepts and evidence), 3) Context-specific pedagogy (resolution of misconceptions, teacher-student relationship, modification of teaching strategies to facilitate students' understanding), 4) Content knowledge (use of exemplars, coherent lesson, balance between depth and comprehensiveness, accurate content). Each criterion has a rating score from 1 to 5. The highest score one can get from the SCOR is 90.

The pre-service physics teachers' lesson plans were also the data source to understand how they planned to integrate CBL technology into their physics teaching. Semi-structured interviews were conducted with the participants just after their practices to understand their knowledge of CBL technology integration. They were asked the best way of using CBL technology in the class, how they preferred to use CBL technology into their teaching, how they integrated the CBL technology into their practices, what they did to provide students for reaching and producing knowledge while using CBL technology, and what benefits CBL technology could provide. The interviews were done in the researchers' offices and lasted 15-20 minutes.

5.3.2 Contextual Factors

5.3.2.1 Qualitative Data

Since this research also focused on the context related factors possibly influencing the pre-service teachers' TPCK, more data were collected associated with the participants' teaching philosophies and their attitudes towards CBL technology by using individual interviews, reflective journals, and surveys.

When teachers' philosophies about teaching and learning are acknowledged and addressed, professional development is more successful in bringing about sustained changes (Levitt, 2001). Teacher philosophies regarding curriculum, teaching, and assessment must be identified and clarified during professional development, because philosophies are strongly associated with behavior and action (Kang & Wallace, 2004). This study aimed at exploring the pre-service physics teachers' instructional philosophies in the following five domains: Learners and learning (LL), Instructional goals (IG), Classroom management and classroom environment (CME), Teachers' role (TR), and Teaching principles, strategies and assessment (TPSA). An in-depth semi-structured interview protocol including 20 open-ended questions under five domains were prepared by considering Teacher Pedagogical Philosophy Interview (TPPI) developed by Richardson and Simmons (1994). Content validity of the questionnaire was ensured by three science educators. The participants were interviewed by the researchers in their offices before their teaching practices. Each interview lasted about 30 minutes and was tape-recorded. Some of the questions under the domains were as follows:

1. Classroom Management and Classroom Environment

- Could you describe the classroom communication (student-student, student-teacher) in your classroom?
- How do you handle classroom management problems?

2. Teacher’s role

- In your opinion, what is the role of the teacher in the classroom?
- Could you make a metaphor for a teacher’s role?

3. Teaching principles and strategies

- How do you decide when to move from one concept to another?
- How do you decide which teaching strategies/methods do you use for your lesson?

4. Learners and Learning

- Describe how you believe students learn physics?
- Does learning physics require special ability?

5. Instructional Goals

- What would be your goals for your students in learning physics?
- How do you want students to view physics by the end of the school year?

The participants’ awareness of their teaching and instructional decision making were identified with the help of interviews conducted just after their teaching practices. Semi-structured interviews were conducted by the researchers in their offices and each interview took about 15 minutes. The following questions some of whom were prepared by Lowery (2002) were asked during the interviews:

1. What strengths when teaching physics do you bring to the classroom?
2. What weaknesses when teaching physics do you bring to the classroom?
3. What formal experiences do you believe have influenced your teaching practices?
4. What formal experiences do you believe have influenced your conception of teaching?
5. What specific teaching skills and/or techniques do you feel you are performing well?
6. On which teaching skills and/or techniques do you need to improve?
7. How do you plan to improve the items mentioned in the previous question? Please be specific.

The participants were required to answer three open-ended questions prepared by Flick, Gamble and O-Connor (2001) in their reflective journals to assess their knowledge of technology in physics education. The questions were:

1. What meaning do you attach to the term “technology” for the purposes of physics instruction?
2. What should students learn about technology?
3. What do you see as the relationship between teaching about technology and physics education?

The participants’ awareness of CBL technology usage in their teaching was examined with the following questions asked them in their journal after their CBL technology implementation:

1. What were the advantages of using CBL technology in your teaching?

2. What were the disadvantages of using CBL technology in your teaching?
3. What did you/could you have done to eliminate the disadvantages?

5.3.2.2 Quantitative Data

How technology is being used is also dependent upon teachers' attitudes (Dusick, 1998; Gado, Ferguson, & van 't Hooft, 2006; Judson, 2006). The Attitude Toward Self as Science Teacher survey (Carrie and others, 1996) consisting of 20 five-point Likert scale items from “strongly disagree” to “strongly agree” was used to determine the pre-service teachers' attitudes toward teaching. The participants filled out the survey during the class time at the end of the fourth week of the semester and just before starting their technology integration practices. The survey indicated the respondent's self-reflection as a science teacher. Example items from the survey were:

- I have positive feelings about my preparation for teaching science.
- I feel I have the skills necessary to inspire student to want to learn about science.
- I feel uneasy about the prospect of teaching science.

The participants’ attitudes toward CBL technology were assessed by administration of the CBL Technology Attitude Scale. This scale was adapted from Technology Attitude Scale developed by McFarlane, Hoffman and Green (1997) by changing the word technology into CBL technology. There were 20 seven-point Likert scale items from “not all true of me” to “very much true of me”. The following items were in the scale:

- Knowing how to use CBL technology is a necessary skill for me.
- I am not the type to do well with CBL technology.
- I feel confident with my ability to learn about CBL technology.

Although teachers acknowledge the effectiveness of technology in the teaching and learning process, their actual of technological tools may be affected by how easy they are able to integrate technology effectively in their classrooms (Owusu, 2014). The Final Technology Skill Survey (Reid-Griffin, 2003) was applied to the pre-service teachers to measure their CBL technology skills. There were eight five-point Likert scale items from “strongly disagree” to “strongly agree” related to data collection and analysis by using graphic calculator and probes. The CBL Technology Attitude Scale and the Final Technology Skill Survey were administered to the participants at the end of the semester during the class time. Some of the items from the survey were as follows:

- By using the data analyzer, probes and motion detector, I can easily collect and analyze data.
- I can create graphs using the data collected on the graphing calculator.
- I am able to solve problems using the graphing calculator, data analyzer, probes and motion detector.

5.4 Data Analysis

5.4.1 Data Analysis for TPCK

Mean values of the SCOR’s scores given by two researchers were calculated for each criterion to determine the participants’ CBL technology integrating practices. Internal consistency of the SCOR computed by Cronbach’s Alpha formula was high, with reliability coefficient of .91 for the first researcher’s observation and with reliability coefficient of .85 for the second researcher’s observation. 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 .60 or .70 (Wood, 2007). Consequently, the coding done for the participants’ practices had adequate reliability. The minimum score is 18, whereas the maximum score is 90 in the SCOR. Therefore, if one’s score was between 18 and 36, his/her technology integration skill was coded as needs improvement; if one’s score was between 37 and 54, his/her skill was coded as medium; if one’s score was between 55 and 72, his/her skill was coded as good; and finally if one’s score was between 73 and 90, his/her skill was coded as sophisticated.

The participants lesson plans were analyzed by using an assessment instrument consisting of 20 items with three-point rating scale (unsatisfactory, somewhat satisfactory, satisfactory) developed by Timur (2011) for lesson plans including technology implementation. The highest score one can get from the technology lesson plan scale is 60. Similar coding scheme was used for the lesson plans. Thus, the score between 20 and 30 was coded as needs improvement, the score between 31 and 40 was coded as medium, the score between 41 and 50 was coded as good, and the score between 51 and 60 was coded as sophisticated. Some of the items in the scale were related to:

- Identification of lesson objectives correctly.
- Identification of students' prior knowledge.
- Determination of appropriate technology for the purpose of the lesson.
- Determination of appropriate technology for students' levels.
- Integration of technology in accordance with constructivist approach.
- Assessment of students' learning while they are using technology.
- Having Plan B in case of any technology inconveniency.

Two researchers compared their coding and were able to reach 93 % agreement with .80 Cohen's κ reliability.

According to Irving (2003), educational technology becomes an information delivery system in the knowledge-transfer mode. On the other hand, educational technology in the knowledge-construction mode offers instructional strategies to present information and provide guidance on how to process that information, what to take note of, how to mentally organize the information, and how it relates to prior knowledge (Irving, 2003). In order to analyze the participants' knowledge of CBL technology integration, their responses to the interview questions were transcribed and arranged in themes (Riessman, 2008). A three-point rating scale (does not know, somewhat knows, knows) instrument consisted of 10 items was created by the researchers to analyze the transcripts. The rationale behind this scale was integrating and using CBL technology as a learning tool (Inan & Lowther, 2010) consistently with the constructivist approach, that is the knowledge-construction mode. The score one can get from the scale was between 10 and 30. Consequently, the following scoring range and coding were used: 10-15: needs improvement, 16-20: medium, 21-25: good, and 26-30: sophisticated. The following items can be given as examples from the scale:

- Utilization of CBL technology as a tool for learning by doing hands on science.
- CBL technology provides students for showing their understanding.
- CBL technology increases students' thinking in social constructivist environment.
- Utilization of CBL technology as a tool to help students construct hypothesis.
- CBL technology helps students give scientific explanations.

The agreement between two coders was 94 %. The reliability measured by Cohen's κ was .83. Numbers were assigned to the codes to determine the pre-service physics teachers' TPCK related to CBL by including their knowledge and skills that they reflected to their teaching practices, lesson plans, and interviews. Hence, "1" was assigned to "needs improvement", "2" was assigned to "medium", "3" was assigned to "good", and "4" was assigned to "sophisticated". The participants' TPCK levels related to CBL technology were identified by calculating the mean of the numbers they got from CBL technology integration practices, lesson plans, and knowledge of CBL technology integration, and then turned into codes again by using the conversion given in Table 2.

Table 2. The Participants' TPCK Levels Based on the Mean Values

Mean	Category
1 – 1.75	Needs improvement
1.76 – 2.50	Medium
2.51 – 3.25	Good
3.26 – 4.00	Sophisticated

5.4.2 Data Analysis for Contextual Factors

Intensive qualitative data analysis was done to understand the pre-service physics teachers' instructional philosophies. After transcription, the participants' responses were grouped under five domains and analyzed thematically (Riessman, 2008). The themes were determined and the data under each domain were coded as teacher-centered, transitional, and student-centered based on the literature.

Student-centered philosophy is "based on a theory of learning that suggests that understanding arises only through prolonged engagement of the learner in relating new ideas and explanations to the learner's prior knowledge" (Ravitz, Becker, & Wong, 2000, p.1). Teacher-centered philosophy, on the other hand, is "based on a theory of learning that suggests that students learn facts and concepts and they understand by absorbing the content of their teacher's explanations or by reading an explanation from a text and answering related questions" (Ravitz, et al., 2000, p.1). A classroom environment where both teachers and students initiated and answered questions; students interacted with each other, worked collaboratively, were given opportunities by the teacher to think aloud, and were intellectually active was considered as student-centered. In the teacher's role domain, teachers who saw their roles as providing knowledge, skills, and answers, and assigning specific tasks to students were considered as teacher-centered. In contrast, facilitating critical student inquiry, providing students with opportunities for cognitive disequilibrium, and questioning to help students to think through an issue for themselves were considered as student-centered (Holt-Reynolds, 2000). For the instructional goals domain, selecting content for teaching based on students' interests, prior knowledge, and particular learning needs, and organizing knowledge and skills in such a way that relationships among them were obvious were considered as student-centered. In teacher-centered instruction, teachers plan lessons along with a sequence of content while beliefs about how students learn or the resources needed become a secondary concern (Hoban, 2003). Conversely, in student-centered instruction, primarily focuses on how students learn; thus, students' prior knowledge is taken into account and social interactions with peers and the teacher are structured (Hoban, 2003). Teacher-centered practice is rooted in the behaviorist theory where knowledge is viewed as a commodity to be transferred to students whose responsibility is to learn it in a way that is faithful (Gallagher, 1993). In student-centered practice, teachers are engaged in thinking about their students' understanding of the subject matter, and they think about new practices, such as group work and writing to learn to examine their own teaching and their students' learning (Gallagher, 1993). Teaching activities such as providing non-routine applications of previously learned knowledge and accommodating individual students' interests, needs, and abilities were considered as student-centered. Assessment techniques such as journal writing, open-ended problems, projects etc. were considered as student-centered. One more category, i.e., transitional, was also used as applying to instructional philosophies to imply a domain where both teacher-centered and student-centered themes equally existed. To assess the reliability of this coding, the second researcher randomly selected 25 % of the questions (5 questions) from the interview protocol and coded the participants' instructional philosophy. Then, the two researchers compared their coding and were able to reach 93 % agreement. The reliability measured by Cohen's κ was .84.

The participants' responses from the interviews were transcribed and grouped and a three-point rating scale (unaware, somewhat aware, aware) with seven items was generated to analyze their awareness of their teaching and instructional decision making. Some items were related to awareness of strengths and weaknesses brought to the classroom during teaching, and awareness of experiences influencing teaching practices and conception of teaching.

Their knowledge of technology in physics education was analyzed with the help of a three-point rating scale (does not know, somewhat knows, knows) consisting of three items. Their written responses from their journals were rated as if they knew technology was an any tool to get something done better or faster, technology was all kinds of equipment/machines, and students needed to learn how to use technology, pros and cons of technology, and that technology was changing. The pre-service physics teachers' responses were also rated if they knew using technology adequately and effectively as an instructional tool to construct physics knowledge.

To analyze the participants' awareness of CBL technology usage intensively, a three-point rating scale (unaware, somewhat aware, aware) composed of three items was generated to score their answers in their journals. The pre-service physics teachers were examined if they were aware of advantages and disadvantages of using CBL technology and what to do to prevent the disadvantages.

Descriptive statistics were performed to analyze quantitative data and intensive analysis as well as generated rating scales were used to analyze qualitative data. The reliabilities of the instruments were established by examining the internal consistency (Cronbach alpha reliability coefficient). Alpha coefficient for the Attitude Toward Self as Science Teacher survey was .91 showing its high reliability. Alpha coefficient for the CBL Technology Attitude Scale was .85 meaning that the scale had high reliability. Final Technology Skill Survey had medium level reliability with .47 Cronbach Alpha value. Regarding interviews and document analysis, two researchers analyzed the data and compared the codes to calculate reliability coefficient and Cohen's κ value. Percentages of agreement were 92 % for awareness of their teaching and instructional decision making, 90 % for knowledge of technology in physics education, and 94 % for awareness of CBL technology usage. Cohen's κ values were .81, .80, and .85 respectively. Since each pre-service teacher was handled as a case, both between and within case analysis were carried out (Ritchie and Spencer, 1994).

To find an answer to the question about how the contextual factors handled in this research influenced the participants' TPCK, the differences between minimum and maximum scores of the factors were divided into four and the levels were coded as needs improvement, medium, good and sophisticated respectively. For instance, the participants' instructional philosophies were evaluated as teacher-centered, transitional, and student-centered in each domain. These levels were labeled from 1 to 3. Since their philosophies were examined in five domains, the minimum score one can get was 5 while the maximum score one can get was 15. As a result, scores from 5.00 to 7.50 was coded as needs improvement, from 7.51 to 10.00 was coded as medium, from 10.01 to 12.50 was coded as good, and from 12.51 to 15.00 was coded as sophisticated. Moreover, the minimum score one can get from the CBL technology attitude scale was 20 whereas the maximum score one can get was 140. Consequently, scores from 20 to 50 was coded as needs improvement, from 51 to 80 was coded as medium, from 81 to 110 was coded as good, and from 111 to 140 was coded as sophisticated. Non-parametric Spearman's rank-order correlation analysis was performed to look for statistical relationships.

6. Results and Discussion

6.1 The Pre-Service Physics Teachers' TPCK Related to CBL Technology

Table 3. Mean Values of the Participants' Scores from the SCOR in Each Category

	Mean values in the categories of the SCOR			
Participants	FLPCP	CTSP	CXSP	CK
Sally	4.60	4.00	4.00	4.25
Orlando	4.20	3.83	4.30	4.00
Naomi	4.40	4.50	3.66	4.75
Debra	4.40	4.50	3.66	4.75
Elise	4.40	4.66	4.30	4.50
Daphne	4.80	4.83	4.66	5.00
Vick	4.40	3.50	4.33	4.00
Zara	3.60	4.00	3.66	4.75
Sawyer	5.00	4.80	4.33	5.00
Nancy	4.40	5.00	4.66	5.00
Average Mean	4.38	4.33	4.19	4.52

FLPCP: Facilitating the learning process from a constructivist perspective, CTSP: Content-specific pedagogy, CXSP: Context-specific pedagogy, CK: Content knowledge

The mean values of the participants' scores from the Science Teaching Observation Score (SCOR) in each category are shown in Table 3. Average of the mean values of each category was also calculated. High mean values represented that the pre-service physics teachers had skills to integrate the CBL technology into their practices successfully. They got the highest scores in the Content Knowledge category (average mean = 4.52) because they could use verbal and visual models, teach concepts and skills coherently, balance depth and comprehensiveness, and use accurate content. Daphne, Sawyer and Nancy received 5 from all the criteria in this category. The participants' scores in the Facilitating the Learning Process from a Constructivist Perspective category were generally high (average mean = 4.38) as they could provide student engagement in activities and novelty. 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. Sawyer was the only one who got 5 from all the criteria in facilitating the learning process category whereas Zara earned the lowest scores (mean value = 3.6) because the students were partially engaged in initiating examples and asking questions at times during the lesson and novelty, newness, discrepancy, or curiosity were used sometimes to motivate learning. On the other hand, the participants did not get high scores in the criteria of dissolution of misconceptions and change in teaching methods to facilitate understanding, both of whom were under the category of Context-Specific Pedagogy category (average mean = 4.19). Their scores in these practices 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. Therefore, nobody could not get the highest score in this category. The participants' scores were generally high regarding the Content-Specific Pedagogy category (average mean = 4.33) due to the fact that their activities facilitated conceptual learning, they considered individual interest, used various kind of teaching strategies and promoted higher order thinking skills. Nancy's performance was top of the class in this category. However, Vick got the lowest scores (mean value = 3.5) in content-specific category because concepts and evidence were loosely connected and sometimes he drifted away from student relevance, but brought the lesson into focus quickly.

The participants' TPCK according to their levels in knowledge of CBL technology integration, lesson plans, and CBL technology integration practices are presented in Table 4. In regard to Table 4's second column, except for Vick's practice, all the participants' teaching practices were sophisticated while using technology and their scores were between 73 and 90. As it was also explained with the help of Table 3, the pre-service physics teachers 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 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 for the participants' sophisticated practices might be their familiarity with laboratory experiments because they used the CBL technology to do experiments. These results were similar with the result revealed by Wetzel (2001), who found that technology had positive influence on pre-service teachers' practices.

Regarding Table 4, 70% of the participants prepared either good or sophisticated lesson plans (see the third column). For example, Zara's lesson plan received the highest score (52 out of 60) among the participants' lesson plans and evaluated as sophisticated. In addition, Orlando's lesson plan score was 43, which was good. However, some of the participants (Elise, Daphne, and Vick) had difficulties in reflecting technology integration into their lesson plans. Apart from Naomi, none of the pre-service teachers planned an appropriate closure for the lesson such as explaining what would be done in the next lesson. 80% of the participants did not consider how to assess the students' learning by using technology. Moreover, 70 % of the pre-service physics teachers neither considered time loss due to technology settings nor provided detailed explanation about episodes of the lesson. Nevertheless, they could allocate the necessary time for the activities, state their purposes for the lesson and specify performance objectives.

Table 4. Participants' TPCK Levels in terms of Their Levels in Knowledge of CBL Technology Integration, Lesson Plans, and Technology Integration Practices

Participants	CBL Technology Integration Practices	Lesson Plan for CBL Technology	Knowledge of CBL Technology Integration	TPCK related to CBL
Sally	Sophisticated	Good	Sophisticated	Sophisticated
Orlando	Sophisticated	Good	Medium	Good
Naomi	Sophisticated	Sophisticated	Sophisticated	Sophisticated
Debra	Sophisticated	Good	Sophisticated	Sophisticated
Elise	Sophisticated	Medium	Sophisticated	Good
Daphne	Sophisticated	Medium	Needs improvement	Medium
Vick	Good	Medium	Medium	Medium
Zara	Sophisticated	Sophisticated	Good	Sophisticated
Sawyer	Sophisticated	Good	Needs improvement	Good
Nancy	Sophisticated	Good	Sophisticated	Sophisticated

The fourth column of Table 4 presents that a half of the participants (Sally, Naomi, Debra, Elisa and Nancy) sophisticatedly knew how to use CBL technology as a tool to construct knowledge. For instance, Debra thought that in order to integrate CBL technology into the lesson, declarative knowledge should not be transferred to students directly. She stated that students must be thought how to use technology and how to be assessed by using technology. She also added that students must construct hypothesis, define how to setup the experiment by using CBL technology and discuss inferences obtained from the experiment. Therefore, she got the highest score and her knowledge on CBL technology integration was evaluated as sophisticated. Vick expressed that if technology was used as a facilitator to transfer information, the learning environment would not be student-centered. However, he could not explain teachers' and students' roles where technology was used as a tool. Therefore, his knowledge was coded as medium. Moreover, Daphne and Sawyer needed to improve their knowledge in this issue. Daphne could not distinct the difference in technology using strategies between student-centered and teacher-centered. In addition, according to Sawyer's perception, if there was a technology in the instruction in one way or other, the instruction was already congruent with constructivism.

The last column of Table 4 illustrates the participants' TPCK related to CBL. Even though none of the participants needed improvement in their TPCK, Daphne and Vick had medium level TPCK because of their limited knowledge of technology integration and lesson plans. While a half of the participants had sophisticated TPCK related to CBL, 30 % of the participants' TPCK was in good level. These high levels indicate that the pre-service physics teachers had tendency to use technology and did not struggle much to integrate CBL technology into their practices. While they were using technology, they felt sure of themselves. 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.

6.2 Contextual Factors

The pre-service physics teachers' instructional philosophies in five domains are shown in Table 5. Sally, Debra, and Elise owned student-centered philosophy in all domains. Orlando and Zara held student-centered philosophy in four domains and transitional philosophy in one domain. Apart from Sawyer, who had teacher-centered philosophy in learners and learning domain, none of them owned teacher-centered philosophy in any domain. Naomi, Daphne and Nancy, on the other hand, had transitional philosophy in two domains.

Table 5. The Pre-Service Physics Teachers' Instructional Philosophies in Five Different Domains

Participants	LL	IG	CME	TR	TPSA
Sally	SC	SC	SC	SC	SC
Orlando	T	SC	SC	SC	SC
Naomi	T	SC	T	SC	SC
Debra	SC	SC	SC	SC	SC
Elise	SC	SC	SC	SC	SC
Daphne	T	SC	SC	SC	T
Vick	SC	T	T	SC	T
Zara	SC	SC	SC	SC	T
Sawyer	TC	T	SC	T	T
Nancy	SC	SC	T	T	SC

SC: student-centered, TC: teacher-centered, T: transitional, LL: Learners and learning, IG: Instructional goals, CME: Classroom management and classroom environment, TR: Teacher's role, TPSA: Teaching principles, strategies and assessment.

Results also presented that except for two participants, the pre-service physics teachers owned student-centered instructional philosophy in the domains of teacher's role and instructional goals. For example, Debra said that: "I see myself as a guide who helps students to achieve scientific knowledge. Teachers are like a bridge between public and scientists" (TR domain). Most of the pre-service physics teachers held student-centered instructional philosophy in the classroom management and environment domain. For instance, Orlando stated that: "There needs to be love and respect between me and my students. Discourse in the classroom should be dialogical. I should be able to establish empathy with my students". However, there were some teacher-centered patterns in the participants' instructional philosophy related to the learners and learning domain and teaching principles, strategies and assessment domain which were coded as transitional. According to Daphne, "....Not everybody could learn physics. Physics learning requires math knowledge and numerical talent" (LL domain).

The pre-service physics teachers' levels in contextual factors are demonstrated in Table 6. Almost all of the participants (80 %) had sophisticated instructional philosophy with regards to the third column of Table 6. This result is compatible with the result presented by Brown and Melear (2006), Luft, Roehring and Patterson (2003) and Levitt (2001) who explored that teachers espoused certain nontraditional beliefs about the teaching and learning of science and these nontraditional beliefs accorded with the philosophy of current science education reform.

Table 6. The Participants' TPCK levels related to CBL and Their Levels in Contextual Factors

Participants	TPCK related to CBL	Instructional Philosophy	Awareness of Teaching	Knowledge of Technology	Awareness of CBL usage	Attitude toward Teaching	Attitude toward CBL	CBL Technology Skills
Sally	Sophisticated	Sophisticated	Sophisticated	Sophisticated	Sophisticated	Good	Good	Sophisticated
Orlando	Good	Sophisticated	Good	Medium	Sophisticated	Sophisticated	Sophisticated	Sophisticated
Naomi	Sophisticated	Sophisticated	Good	Good	Good	Good	Good	Good
Debra	Sophisticated	Sophisticated	Sophisticated	Good	Sophisticated	Sophisticated	Sophisticated	Sophisticated
Elise	Good	Sophisticated	Sophisticated	Sophisticated	Sophisticated	Good	Sophisticated	Sophisticated
Daphne	Medium	Sophisticated	Good	Medium	Good	Good	Sophisticated	Sophisticated
Vick	Medium	Good	Good	Good	Sophisticated	Sophisticated	Good	Sophisticated
Zara	Sophisticated	Sophisticated	Good	Sophisticated	Sophisticated	Sophisticated	Sophisticated	Sophisticated
Sawyer	Good	Medium	Sophisticated	Sophisticated	Good	Sophisticated	Sophisticated	Good
Nancy	Sophisticated	Sophisticated	Sophisticated	Good	Sophisticated	Good	Sophisticated	Sophisticated

Regarding Table 6, half of the participants' levels of awareness of their teaching and instructional decision making were sophisticated while other half of them had good awareness (see the fourth column). For instance, during the interview Elise stated that "Before a lesson, I am making plans and preparing activities for my students to make them participate in the lesson. I am trying to explain my knowledge understandably by giving various examples. However, I become nervous in the beginning of the lesson and this causes me structuring my sentences improperly. I am not good at using the board efficiently. I need to work on this and improve my teaching skills.". It seemed that Elise was very much aware of her strengths and weaknesses about her teaching; hence, she got the highest score from the rating scale and her awareness was valued as sophisticated.

The participants' knowledge of technology in physics education was determined with the help of reflective journals. According to the results, the participants' knowledge of technology was not as high as their instructional philosophy (see the fifth column of Table 6). Two participants' (Orlando and Daphne) knowledge of technology was in medium level and 40 % of the participants had sophisticated knowledge. For instance, Sawyer, whose rating scale score was very high, wrote that "Technology is a product of using science (especially physics) as a tool. But it also serves physics. Physics is a natural science and founded on observations and experiments. Observations and experiments should be done sensitively to learn physics. Therefore, technology should be learned and used. Technology is produced by humans to be beneficial for humans and it helps teachers and students.". From Sally's point of view, who also held sophisticated technology knowledge, "students need to learn technology to integrate it in their lessons and to adopt changes as well as improvement in education". On the other hand, Orlando neither wrote the benefits of technology nor knew that technology must be integrated in teaching and learning physics. As a result, his knowledge of technology was evaluated as medium level. Forssell (2011) claims that strong TPCK relies more on strong pedagogical content knowledge than on strong technology knowledge. Although some technology knowledge may be needed for TPCK, the standard may be quite low (Forssell, 2011).

Results presented that majority of the participants (70 %) had sophisticated awareness of CBL technology usage because they realized the advantages and the disadvantages of integrating CBL technology into their teaching practice (see the sixth column of Table 6). For example, Vick wrote in his journal that: "During the CBL activities, the students worked in a group and shared their duties. They worked collaboratively and reached scientific knowledge all together". Nancy also stated that: "CBL provided discussion in the class. As CBL experiments took up less time, the students were able to finish data collection and analysis in a shorter time. Therefore, they could have more time for interpretation and discussion of the results. They would not forget new information they learned". Sally mentioned some problems related to CBL technology: "I think, designing a lesson is very crucial for teachers. Sometimes I had some technical problems while using CBL like connection problems, so teachers should have a back-up plan of their lessons". Naomi, Daphne and Sawyer had good awareness of using CBL technology because they did not make any comment about the disadvantages of using this technology. The participants' ideas about advantages and disadvantages of using CBL technology and precautions they considered to eliminate the disadvantages are presented in Table 7.

Table 7. The Pre-Service Physics Teachers' Awareness of Using CBL Technology

Participants	Advantages of CBL	Disadvantages of CBL	Precautions taken to eliminate disadvantages
Sally	Supports visuality	Some technical problems of CBL,	Back-up plan,
Orlando	Student friendly usage, Facilitates teachers' role in the class,	Limits teachers' creativeness,	
Naomi	Provides having concrete experience,		
Debra	Allows critical thinking, Increases student motivation, Enables group working,	Teachers' limited experience with CBL usage,	Spending more time with CBL,
Elise	Supports accurate measurements, Provides learning science with doing experiments,	Students may become lazy about drawing a graph,	Comparison of CBL graphs with hand driven graphs,
Daphne	Provides reliable measurements, Exciting tool for students,		
Vick	Supports collaborative learning, Facilitates understanding of graphic construction,	Teachers' inability to use CBL or any other technology,	Making more practice to integrate CBL into teaching,
Zara	Draws alternative path for learning and teaching,	Sensitive sensors,	
Sawyer	Enables real-time data collection, Provides time management,		
Nancy	Gives a chance to reach permanent knowledge, Motivates teachers to teach, Provides eagerness to learn science,	Incorrect measurements can lead students inaccurately,	Teachers can interfere in incorrect measurements,

While half of the participants' attitudes toward teaching were sophisticated, half of them had attitudes in good level with regards to the seventh column of Table 6. The pre-service physics teachers expressed their confidence in preparation to teach science and a sense of looking forward to teaching science to students. Debra, who held sophisticated attitude, believed that she would convey an enthusiastic attitude towards science to students and thought that teaching science would be an enjoyable experience. However, Daphne's attitude was in good level because she considered her background did not prepare her to teach science and motivating students to want to learn about science was difficult.

Most of the participants (70 %) showed sophisticated attitudes toward CBL technology (see the eighth column of Table 6). Zara's attitude was sophisticated due to the fact that she liked using CBL technology and believed that learning about CBL technology was a worthwhile and necessary subject for all pre-service physics teachers. Nancy's opinion about importance of knowing CBL technology in finding a teaching position had an efficient role in her sophisticated attitude. Nevertheless, Sally, Naomi and Vick felt uneasy and confused while using CBL technology. Their ideas about disadvantages of using CBL technology support this finding.

According to Table 6, almost all of the pre-service physics teachers (80 %), apart from Naomi and Sawyer, had sophisticated CBL technology skills. They strongly agreed that the data collection activities using the probes and motion detectors increased their enjoyment in learning math and science. They also declared that they could determine changes in temperature using temperature probes. However, Sawyer could not agree with the statement that the data collection activities make science and math more interesting.

By taking Table 6 into account, each participant was examined to understand which contextual factors might potentially affect his/her TPCK. For instance, Orlando held good TPCK and his awareness of teaching and instructional decision making was in good level. Though Vick had medium level TPCK, none of the factors was in medium level. On the other hand, in parallel to Zara's sophisticated TPCK, all the factors, except for awareness of teaching, were in sophisticated level. Therefore, within case analysis revealed that all the seven contextual factors taken into account in this research had potential to influence the participants' TPCK.

Between case analysis and frequency counting exposed that three factors (instructional philosophy, awareness of CBL usage, and CBL technology skills) among seven factors were in the same level with the participants' TPCK most of the time (five times). According to the Spearman's rank-order correlation analysis results, there was a nearly strong positive relationship between instructional philosophy and TPCK ($\rho = 0.68$, $p < .05$) and there was a strong positive relationship between awareness of CBL usage and TPCK ($\rho = 0.76$, $p < .05$). This statistical results supported the result of between case analyses. Ertmer (2005) suggests that teachers will make effective, high-level, use of computers in their classroom instruction only if their personal beliefs are aligned with student-centered, constructivist pedagogy.

7. Conclusions, Suggestions and Implications

Teachers must not focus on the technology itself, but rather on the learning outcome that is supported by technology (Millen & Gable, 2016). 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). Teachers' use of technology in their teaching can be a result of how they were prepared during their initial teacher education program (Kay, 2006). Accordingly, this study explored pre-service teachers' TPCK.

The following conclusions can be drawn from the study: First, pre-service physics teachers can reflect CBL technology integration skills into their practices more successfully than to their lesson plans. That is, they can behave like an expert while using CBL technology in their teaching; however, they slightly omit CBL technology from their plans. Second, although they know how to use CBL technology effectively, some of them need to improve their knowledge of CBL technology integration and learn that technology is effective when it is used to construct knowledge. They need to realize that technology is not a vitamin whose mere presence catalyzes better educational outcomes (Dede, 2001). Third, pre-service physics teachers have high level TPCK related to CBL; hence, they have tendency to use CBL technology as a learning tool and have a coherent knowledge about this technology, pedagogy and content. Since this was a case study, the conclusions cannot be generalized to all pre-service physics teachers. This study also concludes that instructional philosophy and awareness of CBL technology usage have significant impacts on their TPCK related to CBL. Having student-centered instructional philosophy and awareness of the specific technology integrated into instruction would contribute performing sophisticated TPCK. Therefore, it is suggested that teacher education programs should work on to develop and improve pre-service teachers' philosophies whose sources, according to Richardson (1996), are personal life experiences, experiences as a student with schooling and instruction, and formal knowledge including pedagogical content knowledge. In addition, this study suggests that pre-service teachers should be given opportunities to realize advantages, disadvantages, and alternative ways of the technology that they try to integrate into their teaching to be more aware of its usage.

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). Hence, various technologies should be introduced in teacher education programs and pre-service teachers should use these technologies as learning tools to gain progress in advancing their TPCK.

The current study contributes to the field by examining pre-service physics teachers' TPCK related to specific technology and some factors influencing their TPCK. The conclusions presented here carry implications for science teacher education because content and context of programs can be regulated to enhance teachers' TPCK.

Though this was a multi case study with ten participants, significant relationships were found between TPCK and two context related factors. Research conducted with higher sample size might reach relationships between TPCK and more contextual factors.

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.

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 the topic being taught, and the technological tool being used (Forssell, 2011). Consequently, the results of this study might not be obtained if different technology had been used and the participants had taught different concepts.

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