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Exploring contextual factors for pre-service teachers teaching with technology through planning, teaching, and reflecting

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ABSTRACT

Teaching with technology is a required skill for today's teachers and the technological pedagogical content knowledge (TPACK) is a commonly used framework that is used to assess the effective usage of this skill. In this framework, teachers' knowledge is assessed under various individual and blended knowledge domains. The effect of contextual factors on TPACK is a relatively recent focal point of this framework. Therefore, this study investigates pre-service teachers' enactment of different TPACK domains and interprets the results according to contextual factors that underlie their decisions and their knowledge levels. For this purpose, a case study involving four pre-service teachers was conducted. The contextual factors are extracted from the pre-service teachers' reflection and teaching philosophy statements. Then their demonstration of TPACK levels are found both during planning and teaching stages. The results indicate that pre-service teachers with low TPACK enactment are mostly preoccupied with contextual elements related to practical concerns, whereas those with higher levels exhibited a greater degree of contextual elements related to beliefs and external priorities. It was also found that this latter group's planning and teaching artifacts are more balanced with respect to TPACK levels, whereas a more significant drop in TPACK levels from planning to teaching was observed for the former group.

Keywords: technology, mathematics education, TPACK, contextual factors

INTRODUCTION

Educating teachers for effectively using technology in their instruction has been a long-standing challenge (Otero et al., 2005). To assess effective integration of technology for teaching and learning, the technological pedagogical content knowledge (TPACK) framework has been extensively used. The TPACK framework (Mishra & Koehler, 2006) is a contemporary interpretation of the Shulman's (1986) original notion of pedagogical content knowledge (PCK). According to Shulman (1986), PCK is defined as the knowledge that '… goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching' (p. 10). The technology dimension in TPACK is rendered necessary by the rapid penetration of digital technologies in every aspect of modern life, in particular for teaching and learning. Tools such as web conferencing, online teaching, dynamic geometry software, statistics and graphing packages, spreadsheets, programming, digital videos, etc. can all be utilized in different ways to improve the efficacy of teaching. Teachers that effectively integrate one or more of these technologies into their teaching while considering their pedagogical implications to deliver the expected content are considered to have TPACK.

Many studies aimed to understand the technology integration of teachers and pre-service teachers alike and found widely different outcomes (Scherer et al., 2017; Schmid et al., 2020; Voithofer & Nelson, 2021; Wang et al., 2018). The differences may be attributed, at least in part, to different contextual factors, which appears to be an oft-overlooked aspect of the TPACK framework (Koehler et al., 2014; Mishra, 2019; Rosenberg & Koehler, 2015). The original TPACK schematic (**Figure 1**) clearly highlights that the knowledge domains that contribute to TPACK and the TPACK itself is enveloped in the circle of contexts and the development of a teacher should not be considered in isolation from this context. Contexts are unique to individuals, classrooms, schools, and districts (Doering et al., 2009). They include practical matters such as access to computers, personal issues such as beliefs and knowledge (Fives & Buehl, 2014) as well as overarching constraints related to educational goals set by regional and national standards. As TPACK is grounded in context, researchers have started to uphold that whether the teacher has TPACK matters less compared to whether he or she can use it in a given context (Rosenberg & Koehler, 2018; Swallow & Olofson, 2017).

Furthermore, understanding the contextual factors that contribute to adoption of TPACK can enable teacher educators to pay attention to these factors in their technology integration courses (Elwood & Savenye, 2015). Questions such as if teachers predominantly use technology for classroom management (CM), time management (TM), external demands, or their beliefs and attitudes toward technology all fall within the domain of contexts (Boschman et al., 2015). Understanding the contextual factors

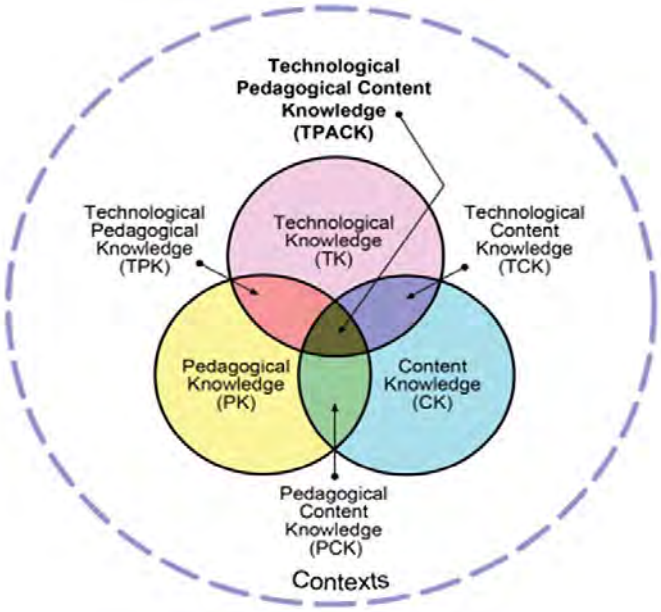

Figure 1. The TPACK framework (reproduced by permission of the publisher, © 2012 by tpack.org)

surrounding technology integration and TPACK can allow for meaningful interpretation of differences between the findings of different studies.

Given this backdrop, this study aims to shed light on technology integration and development of mathematics pre-service teachers using a contextual lens. The specific research questions that are investigated:

1. What are the contextual factors that influence pre-service teachers TPACK enactment during their planning and teaching?
2. What are the influences of these contextual factors on the overall TPACK achievement of the pre-service teachers?
3. What is the relationship between the planning and teaching phases and whether this relationship can be explained by contextual factors?

The significance of these questions come from the fact by understanding the underlying contextual factors pertaining to TPACK for pre-service teachers, one can provide more targeted instruction to support their students' TPACK development. Most students consider TPACK as a set of skills for teaching with technology. However, if they become aware of various contextual factors that they may face when teaching with technology, they may diagnose potentional problems with their own TPACK competence for their future teaching. Furthermore, many studies report TPACK development of pre-service teachers by using self-surveys. Although there are some performance based TPACK studies as well, most studies do not explore contextual factors that may affect TPACK development. Exploring contextual factors is possible only when the researcher has access to a comprehensive set of artifacts of the individuals that are investigated. In this study, pre-service teacher reflections, teaching philosophy statements, lesson plans as well as real classroom teaching sessions were used to conduct an in-depth case study of the underlying contextual factors.

LITERATURE REVIEW

TPACK and Contexts

It is well-accepted that excellence in knowing a subject matter does not directly translate to teaching it well to new learners. The teacher must be aware of the processes through which individuals learn and apply them to teach effectively. This is the domain of PCK, which according to Shulman (1986) is defined as: '… the dimension of subject matter knowledge for teaching' (p. 10). With the advent of digital technologies, a new dimension, namely technological knowledge (TK), has been added to this picture. The combination of TK with PCK was studied by various researchers and adopted various names such as information and communication technology (ICT)-related PCK (Angeli & Valanides, 2005), technologically-enhanced PCK (Niess, 2005), technology, pedagogy, and content knowledge (TPCK) (Koehler & Mishra, 2005), and finally TPACK (Mishra & Koehler, 2006). The TPACK framework has both been extensively used (Voogt et al., 2013) and critiqued (Koehler et al., 2014). Many studies have found that the individual knowledge domains that make up TPACK are either not separable or non-existent in practice (Archambault & Barnett, 2010; Cox & Graham, 2009; Koh et al., 2010; Scherer et al., 2017). Furthermore, most TPACK assessment studies rely on self-reporting surveys, which may not reflect the true knowledge of the participants (Archambault & Crippen, 2009; Chai et al., 2011b; Koehler et al., 2012; Lee & Tsai, 2010; Mishra & Koehler, 2005; Scherer et al., 2017; Schmid et al., 2020; Schmidt et al., 2009). Those that include performance assessment generally use planning artifacts (Akyuz, 2018; Graham et al., 2010; Harris et al., 2010) as opposed to using real-classroom data as was done in this study. However, despite its limitations and the difficulty of assessment, the TPACK framework remains to be a valuable scaffold with respect to which teacher knowledge can be assessed (Hew et al., 2019).

There are many factors that affect teachers' enactment of TPACK such as technological support and other teachers' beliefs (Ertmer et al., 2012; Lai & Lin, 2018), teachers' conversations around interpersonal issues about TPACK (Koh et al., 2014), teachers' technological skills and their valuation of technology (Alayyar et al., 2012; Ertmer et al., 2012), the way teachers see their own identity (Phillips, 2017), and teachers' socially mediated workplace settings (Kaschuluk, 2019; Phillips, 2016). As researchers emphasize, TPACK is grounded in context (Swallow & Olofson, 2017). The importance of context has been recently emphasized by explicitly calling out the outer dashed cycle (**Figure 1**) as contextual knowledge and abbreviating it as XK (Mishra, 2019). Therefore, it is important to investigate the development of TPACK within a specific context in which content, teaching, and learning can be described (Rosenberg & Koehler, 2015; Tabak, 2004). Unless the research captures the complexities of the context during the use of technology for teaching, it is difficult to understand and generalize the effectiveness of this integration (Brantley-Dias & Ertmer, 2013; Graham, 2011; Koehler et al., 2014; Voogt et al., 2013).

In order to understand teachers' effective integration of technology, researchers investigated the interaction in particular context, teacher knowledge development, teacher attitudes towards technology and classroom instruction. Additionally, context has been conceptualized by focusing on the nature of the classroom (Chai et al., 2011a; Chen & Jang, 2019), teachers in their professional life (Young et al., 2012), personal identity (Liang et al., 2013; Phillips, 2017), and teachers' knowledge of students (KOSs) (Shih & Chuang, 2013). Contextual factors can be described under two captions: contextual influences and actors (Porras-Hernández & Salinas-Amescua, 2013). Contextual influences include macro-, meso-, and micro-levels. Macro-level influences are related to socio-political environments and educational policies that govern the use of technology in classes. Meso-level, on the other hand, includes factors that are specific to each school such as the school administration's willingness to integrate technology into their lessons. Finally, micro-level influences are related to '… in-class conditions for learning.' (p. 230). Actors involve both teachers and students. Beliefs and motivations of teachers as well as prior knowledge and misconceptions of students are related to actorial influences. Recent work argues for the importance of macro-, meso-, and micro-levels of context complementing each other to support TPACK development of teachers (Cohen, 2020). Swallow and Olofson (2017) found that micro-level factors that are related to teachers such as their backgrounds, their attitudes towards technology, the way they conceptualize teaching and learning are more influential on TPACK than macro-level factors related to larger social elements. The researchers argue that these components can be accessed by teachers' reflections as they include teacher's own understanding of his or her own individual context. Furthermore, some studies suggest that new and pre-service teachers, despite having higher technological competence, use it less effectively for delivering instruction than their inservice counterparts (Russell et al., 2003). This is attributed to micro-level factors such as being preoccupied with spending most of their time in familiarizing themselves with school's curriculum and CM.

Planning, Teaching, and Reflecting

The cyclic actions of planning, teaching, and reflecting serves an important role for professional development of teachers (Bruce & Chiu, 2015; Gelfuso & Dennis, 2014; Kimmons et al., 2015; Pedro, 2005; Schon, 1983). Hong et al. (2019) investigated the effects of knowledge building principles on pre-service teachers' reflective thinking capacity by using design research. The results showed that the quality of teachers' feedback in the lessons as well as their design knowledge were significantly improved. However, studies also state that less attention was given to develop reflective thinking for pre-service teachers in their practice teaching (Jordan, 2016; Sawyer, 2004). Actually, pre-service teachers are often expected to use more common approaches such as teaching knowledge and skills for direct instructions (Hollingsworth & Ybarra, 2017). However, in order to have teachers that can use their knowledge flexibly, it is important to support their practice not only using pre-defined instructional practices but also less structured and more open-ended instructional practices (Hong & Chai, 2017).

In order to achieve this, it is important to create an environment where pre-service teachers can improve themselves during their teaching practice. One of the ways to create this environment is to ask them to reflect on their strengths and weaknesses in their teaching practices, where they can understand the potential and limitations of their teaching (Hong et al., 2009; Naidoo & Kirch, 2016). Since drill on practice does not require reflective capacity, it is important to support teachers to practice in less structured environments, where they can improve their teaching (Yang & Huang, 2016). Thus, it is important to support reflective approaches that can help pre-service teachers develop their creative teaching process (Radloff & Guzey, 2017; Rusche & Jason, 2011). An environment that is conducive to reflection can be created using design thinking, where teachers first plan a lesson, teach it in the classroom, and reflect on it in a collaborative setting to become better prepared for the next round of teaching (Boschman et al., 2017; Nagro, 2020). Design thinking can also be used to improve teachers' TPACK by giving them opportunities to create collaborative dialogues with their colleagues related to technology integration (Boschman et al., 2015, 2017; Bower et al., 2013; Koh & Chai, 2016; Koh et al., 2015). Furthermore, focusing on teachers' reflections in design thinking might be helpful to understand contextual factors that affect TPACK subdomains in teaching (Swallow & Olofson, 2017). In this study this method of education where the pre-service teachers first prepare lesson plans, then enact their plans in a real classroom was ensued by reflective thinking for both their teaching and planning.

METHOD

As the aim of this study is to explore the technology integration of pre-service teachers during planning and teaching and uncover the contextual factors that govern their practices, an exploratory case study was chosen as a suitable research method. A single holistic case study was conducted to investigate the contextual factors that might influence pre-service teachers' TPACK levels as the pre-service teachers were examined in same middle school in real-life context (Yin, 1994). Additionally, interpretative case study was used as an approach as it is aimed to interpret the context bound phenomena (Merriam, 2009).

Table 1. Rubric for codes

Code	Explanation	Example
CM	Classroom management	I do not know I am supposed to manage a classroom having almost 30 children with different learning styles, characters.
TM	Time management	I think that I may have trouble about time management … Time passes too fast.
KOS	Knowledge of students (needs, misconceptions, prior knowledge)	I also experienced that students cannot solve a question style other than what they are accustomed to.
TSK	Teacher's self-knowledge (knowledge of shortcomings, habits, beliefs)	I think that the ideal teaching approach is authoritative teaching model … I love children so much that I cannot easily get angry at them.
ATT	Attitude toward technology	I plan to use technology for the next lessons because I think that technology both allowed students to discover the concepts in deeper way and increased their motivation.
ATI	Attitude toward inquiry	I plan to start the lesson with word problem … and then try to solve it throughout the class period with inquiry-based tasks and creating discussion environment.
EP	External priorities	Rules should be proper for the class they should not be opposite to the school rules.

Data Collection

The data was collected from pre-service teachers that were enrolled in a major public university in Ankara, Turkey. The official teaching language in this university is English. According to the undergraduate mathematics education program, middle school mathematics pre-service teachers who are in their fourth-year are required to teach 72 hours in one middle school selected by their instructors. Additionally, the instructor needs to observe and assess each pre-service teacher for at least four hours during their teaching. Besides the instructor, the mentor schoolteacher also provides feedback to the pre-service teachers. In this study, the pre-service teachers were randomly assigned to the instructor who is the researcher of this study. Data collection sources included these pre-service teachers' lesson planning artifacts, their reflection statements written after their teaching episodes, teaching philosophy statements, and video transcripts of the teaching episodes. Among eight pre-service teachers that were observed, four of them were selected by using purposeful sampling as they were considered to be rich cases that shed light on the phenomena (Patton, 2014). Ela, Sera, Mina, and Melissa were used as pseudonyms to refer to them anonymously.

Data Analysis

In this study, content analysis was used as the primary qualitative analysis method (Mayring, 2015). For this purpose, all pre-service teachers' lesson plans as well as the transcripts of their teaching sessions were coded using a performance assessment instrument that was recently developed (Akyuz, 2018). This instrument was designed to reveal the distribution of the seven total knowledge domains of TPACK and therefore was suitable for the purposes of the current study. Based on these codes, four of the cases that use technology and exemplify diversity in their TPACK levels were selected. The reflection papers and teaching philosophy statements were also coded to understand the influence of context on the teachers' decisions and differences in their TPACK skills between the planning and teaching phases. To this end, the approach proposed by Boschman et al. (2015) was used by coding the artifacts with respect to three criteria namely practical concerns (i.e., micro-context), existing orientations (i.e., beliefs), and external orientations (i.e., meso- and macro-context). This separation was deemed to sufficiently portray the contextual influences under which the pre-service teachers made their decisions.

In order to apply Boschman et al.'s (2015) categorization of contextual factors further categories were created with respect to statements in the reflections. For this purpose, the rubric shown in **Table 1** was created.

This rubric was created by checking and rechecking the reflection papers and teaching philosopy statements to uncover various categories of items that can be related to context. Among these categories CM and TM were considered to belong to practical concerns with respect to Boschman et al.'s (2015) categorization. KOSs, teacher's self-knowledge (TSK), attitude toward technology (ATT), and attitude toward inquiry (ATI) were grouped under existing orientations. Finally, external priorities (EP) was mapped one to one to its definition in Boschman et al.'s (2015) rubric.

RESULTS

Reflections and Teaching Philosophy Statements

The pre-service teachers' reflections and philosophy statements, both during the semester and after each teaching session, were analyzed with respect to the contextual factors that they contained. The results are summarized in **Figure 2**. Ref.1, Ref.2, and Ref.3 indicate the teaching philosophy statements, whereas LR.1, LR2, LR.3, and LR.4 represent the reflections written after each teaching session. Below detailed descriptions for each pre-service teacher are provided.

Ela–Concerned about classroom management

Ela was initially mostly concerned with CM. She was concerned about how to orchestrate discussions in a classroom with many students. She thought that some students would make noise and distract their friends. These excerpts are from her first reflection:

> … I do not know how I am supposed to manage a classroom having almost 30 children with different backgrounds, different learning styles, and also different characteristics.

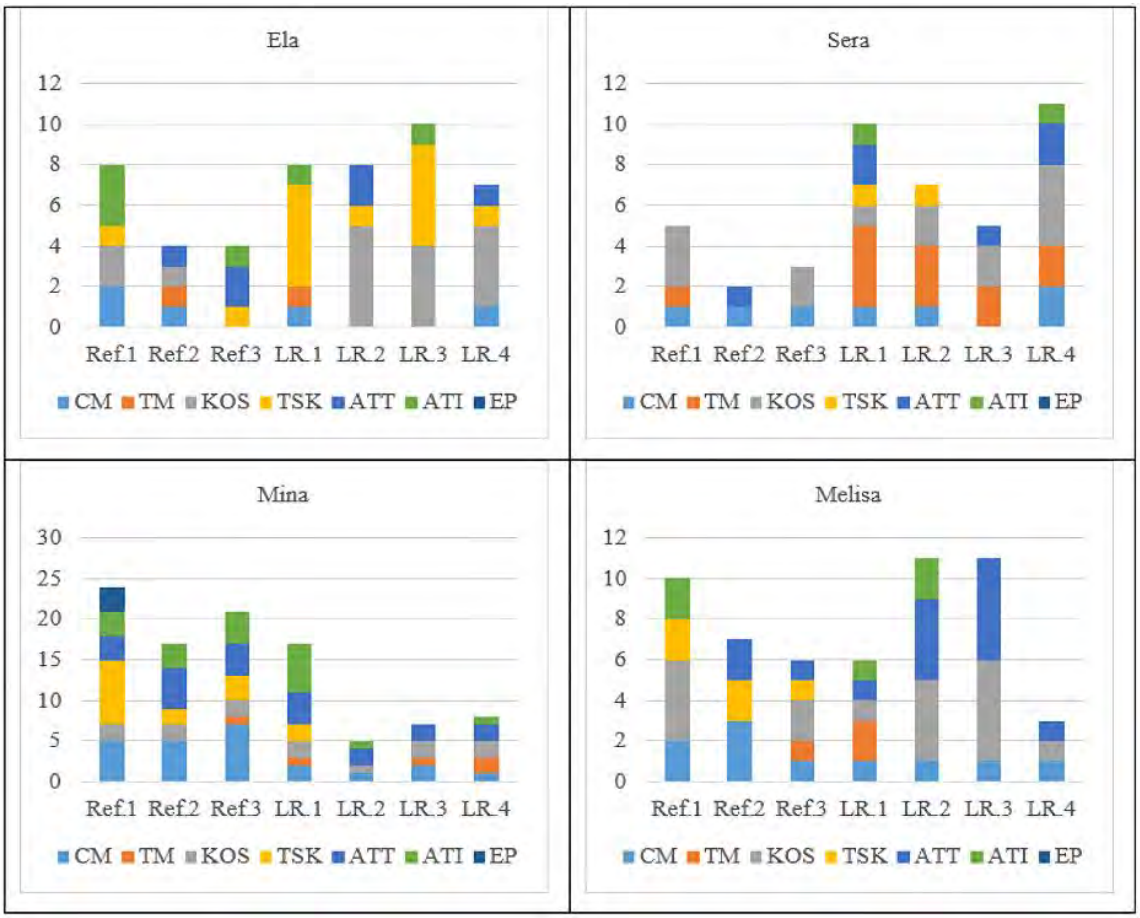

Figure 2. The summary of the contextual factors that the pre-service teachers expressed in their reflections (Source: Author's own elaboration)

> … I know that sometimes there may be challenging students making noise and displaying inappropriate behaviors like disturbing friends, talking too much and etc. Those problems can inhibit other's learning and affect the flow of the lesson negatively.

In her later reflections, she cited problems mostly not due to CM but due to her lack of students' prior knowledge (KOS): "… orchestrating a classroom discussion is very hard and time-consuming, especially when you do not know your students …" Ela's ATT was positive. She mentioned several times that by using technology she was able to attract students' attention. She appeared to use technology to facilitate CM:

> I have used PowerPoint slides to attract students' attention by showing a lemonade mixture at the beginning of the lesson. My aim was to embody the ratio concept and make it lively for students … Using technology like GeoGebra or PowerPoint slides helped me to relax, gave me time to think while students focused on the board and also helped students to engage in lesson more.

However, especially after the second, third, and fourth lessons her reflections indicated the problems she faced due to lack of students' prior knowledge:

> I did not plan to observe some of the misconceptions that students come up with regarding adjacent angles. It was my fault not to focus on misconceptions and remediations of them in case they occur in the classroom while planning the lesson. I could not overcome this misconception because I did not expect that students may give such an idea.

The following is after her third lesson:

> I am deeply sorry to say that I think students did not understand the topic very much. There are some reasons for that. Firstly, I did not know that finding the height of a triangle is very hard for students. I assume that they have already learned that concept.

To summarize, Ela's reflection statements indicated that the primary contextual factors driving her decisions were micro-factors (mostly CM) and existing orientations, especially her lack of self-knowledge as a teacher and students' prior knowledge.

Sera–Concerned about classroom management

Similar to Ela, Sera also initially expressed concerns about not having a good understanding of students' prior knowledge (KOS). In her reflections, she stated that she faced difficulties in both CM and TM. She attributed this to losing time because of the mismatch between what she thought the students know and what they really knew. She made a few statements about the things that she needed to improve herself (TSK). This is an excerpt from her third reflection:

> … When I was planning the course, I thought that the students knew the concept of circle, radius, diameter but the students did not know these concepts. This caused me to experience a little bit of difficulty. I spent a little more time than I planned at the beginning of the lesson.

The following statement was repeated in both of her second and third reflections: "… I need to know the students' prior knowledge. According to their prior knowledge, I need to plan the lesson and set the time". Her reflections included only passing mentions of technology helping students understand mathematics better: "… I used the GeoGebra application for better understanding." Therefore, despite believing that technology would improve students' understanding, her lack of students' prior knowledge did not allow her to use technology effectively. Different from Ela, Sera expressed more concerns about TM as can be seen by the large red bars in the top-right corner of **Figure 2**.

Mina–Aware of external priorities and TPACK

The analysis of Mina's reflections paints a very different picture than both Ela's and Sera's. Firstly, Mina was the only person to mention TPACK in her reflections. She seemed to have understood what TPACK is and why it is important. She even devised a TPACK game by choosing items from three bags one for each of content, pedagogy, and technology, and combining them for teaching. Mina was also an exception by being the only student to mention about EP, which indicates that she was aware of the larger circle of meso-context (school rules). In her first reflection, Mina mentioned about a continuum of teacher profiles from authoritarian to authoritative, and to permissive. She appeared to be confident in her belief that she wanted to take the middle ground by being an authoritative teacher:

> … I think that the ideal teaching approach is authoritative teaching model. To evaluate my weaknesses about the subject, generally I am a smooth person, and I am a person who likes talking. Therefore, I can say that I place in middle between authoritarian and permissive teacher, and I want to be authoritative teacher.

Mina's reflections were dominated by her beliefs about how things should be indicating a high degree of TSK. She made the following comments about the rules in the class:

> … they should be reasonable and necessary for students, they need to be clear and understandable, they should be consistent with instructional goals and the way people learn, and lastly, they should be consistent with school rules.

Mina's reflections were longer than both Ela's and Sera's (note that the y-axis contains larger numbers Mina's chart in **Figure 2**). In her reflections, she frequently demonstrated a positive ATT and how it can help improve student motivation and CM:

> … students really give their attention when it [technology] is used in the class. They were really shocked when they discover any topic via technology. For example, while I taught bisector, I discovered the features of bisector by using GeoGebra. They saw that the ray really divides the angle into two equal parts. While they were discovering I heard 'wow' voices.

In addition to showing a positive ATT, Mina appeared to give high importance to inquiry (ATI) and participation in classroom discussions. She tried to make every student contribute to the class by sharing their ideas. One of her comments was "I saw that even students who are afraid to give a wrong answer can participate in the class when they are waited with respect to respond. That is important for access of all students in class." She added "… all students participated in the discussions; there was no student who did not talk at the end of the lesson … I walked between the students and asked questions like 'your friends say … do you agree with him/her'?" This indicated her desire to make sure that the students were alert about the classroom discussions and actively participated in them. Mina did not make frequent mentions of TM. But she said that her training experience helped her to better plan tasks that can be finished in 40 minutes (one lesson hour). In summary, Mina's reflections exhibited a high degree of self-awareness. She mentioned CM but not in a concerned manner as Ela and Sera did. She believed that inquiry and allowing active participation was important. She believed technology can be a good catalyst for this purpose.

Melisa–Focused on content knowledge and inquiry

Melisa, more than the other three pre-service teachers, appeared to believe in the importance of teacher's own content knowledge (TSK). She emphasized that she expended a lot of effort during her planning to make sure that she understood the mathematical concepts well:

> … It is impossible to teach concepts and wait for students make sense of them without knowing the teacher him/herself. I see clear that if a teacher wants to create a teaching environment where all students understand concepts and do mathematics, the teacher should be qualified … Therefore, before my actual lessons I spent a lot of time to understand mathematical concepts.

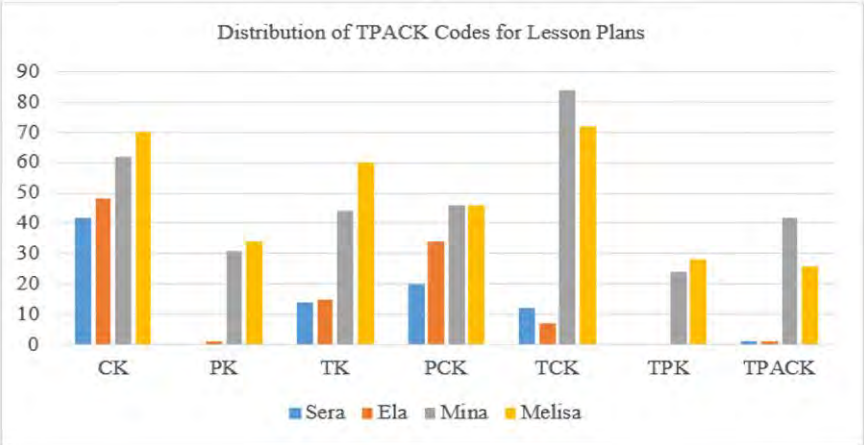

Figure 3. The frequency of TPACK levels observed from the lesson plans of the pre-service teacher (Source: Author's own elaboration)

Another focal point of Melisa was the importance of inquiry (ATI). She mentioned in many episodes that learning by inquiry is very important for students. She generalized by saying that:

> … teachers always teach lessons without giving reasoning or mathematical concept and ask students the same type of questions which can be solved by just using formula. This makes students just use their teachers' way when they encounter a question rather than generating strategies.

She said she want to be a different teacher by "… engaging students to do mathematics with conceptual understanding, relational learning, and critical thinking." Melisa also saw the importance of technology. Similar to her peers she found technology to be particularly effective for CM. But she also emphasized that technology allows for better learning:

> In my both actual lessons, technology, manipulative, and activity sheet helped me to make learning more meaningful. As I said above, students gave 'wow' reaction to the GeoGebra file. It helped both to draw attention to class management and to make meaningful learning.

In Melisa's reflections the issue of TM appeared only once. Melisa had discovered that instead of enacting the activity exactly as planned, if she made some adaptations it helped her to better manage the time:

> I could not arrange the time and I could not finish the activity on time in my first teaching practices. Then I learned that which parts of the lesson plan I should give emphasis and which parts I should not. I tried to change the general look and level of the activity sheet and it was really more effective.

As a whole Melisa appeared to be enthusiastic about technology as it allowed her to give meaning to mathematics while facilitating CM. Melisa's primary focus in her reflections appeared to be her attention to inquiry. She appeared to see technology as a facilitator of both inquiry and CM.

Lesson Plans

Figure 3 summarizes the frequency of TPACK domains observed in the pre-service teachers' lesson plans. The pre-service teachers appear to have been divided into two groups. On one hand, Ela and Sera were found to have lower knowledge in all TPACK domains. Mina and Melisa, on the other hand, showed a higher degree of knowledge in all domains.

Both Ela and Sera mostly focused on the content knowledge (CK) in their lesson plans. Providing sufficient CK to their students appeared to be the central element in their designs. Notably, they showed no measurable competence for the PK, TPK, and TPACK domains. The knowledge domains that include technology such as TCK and TK were found to be weaker compared to those that do not include technology in them (CK and PCK).

Mina and Melisa not only showed a greater degree of awareness for the CK domain than their peers, but also their lesson plans included aspects from all seven knowledge domains. Notably, they both showed a high degree of awareness for the TCK domain. Their pedagogical knowledge (PK) was found to be less than their other knowledge types. This appeared to have been a capping factor for their TPK and TPACK domains as well. Among the core knowledge domains, for all four teachers, the PK domain appeared to be weaker than their content and TK domains based on the evidence from their lesson plans.

Teaching Episodes

The first observation that was made for planning, namely the appearance of two groups of students, held true for the teaching sessions as well. Ela and Sera, who were found to have lower TPACK with respect to their lesson plans were found to have lower TPACK according to their teaching observations as well. As for the individual knowledge domains, the presence of CK appeared to be similar in frequency to those in the planning stage. Although somewhat lower, the TCK domains for all teachers were compatible with the level of their TCK domains for planning.

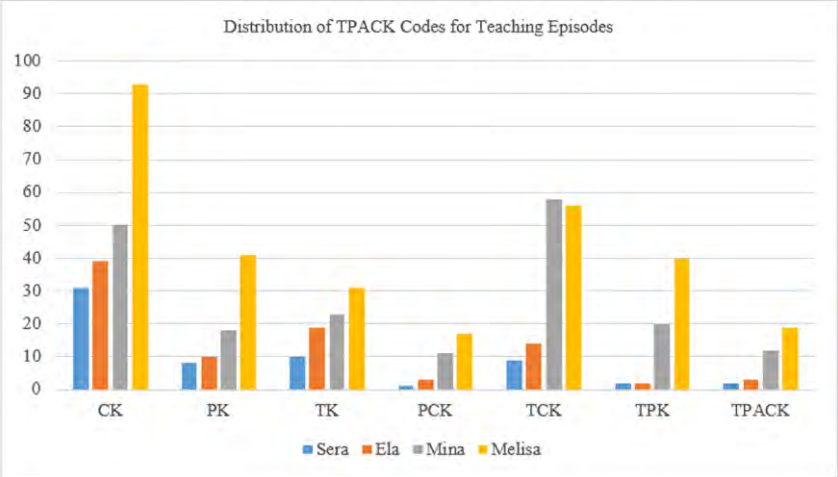

Figure 4. The frequency of TPACK levels observed during the actual teaching sessions (Source: Author's own elaboration)

All other knowledge domains with only a few exceptions appeared to be lower during teaching compared to planning. Among the knowledge domains that decreased, PCK appeared to drop more sharply than the others. The domains that include technology appeared to be impacted less. This could be explained by the teachers' desire to put technology in the forefront of their lessons. The increased emphasis given to technology may have relegated pure PCK to a level of less importance. These findings are summarized in **Figure 4**.

The relationship between the TPACK domains before and during teaching can be better observed in **Figure 5**. Here, it can be seen that the TPACK levels were generally higher during planning (blue bars) compared to teaching (orange bars). Furthermore, it can be seen that overall, there is a greater similarity between TPACK levels of Mina and Melisa between their planning and teaching. This can be understood from the generally balanced sizes of blue and orange bars for these pre-service teachers. However, for Ela and Sera, who were found to be less confident in their TPACK, the imbalance between their planning and teaching TPACK levels appears to be larger. This can be observed by longer blue bars (frequency observed during planning) compared to much shorter orange bars (frequency observed during teaching). In other words, these two teachers appeared to have struggled more when implementing their teaching plans in the real classroom. This could be explained by the increased stress factor associated with teaching especially for novice teachers (Russell et al., 2003).

DISCUSSION

In this study, first underlying contextual factors that may have played a role in the pre-service teachers' technology integration reflected by their TPACK levels were investigated. It was found that the pre-service teachers with lower TPACK levels (i.e., Ela and Sera) mostly concerned with classroom and TM–two elements of the micro-context. They were deeply preoccupied with these concerns that focusing on the actual learning of their students with effective use of technology appeared to be less important. This observation was noted by earlier authors (Russell et al., 2003) as a technology integration difference between novice and experienced teachers. In this study, the chief benefit that Ela and Sera saw for using technology was that it facilitated CM. Given their focus on this micro-context element, it was not surprising to find that they did not demonstrate TPACK in neither planning nor teaching phases of their instruction. Inspection of contextual factors in Mina's reflections yield a different picture than those of Ela and Sera. It was interesting to note that among the four pre-service teachers, Mina was the only one to mention about EP, which can be considered to be related to meso- and even macro-context elements. Furthermore, Mina appeared to be balanced in terms of the contextual factors that were extracted from her reflections.

On the surface, the distribution of Melisa's contextual factors appears to be similar to that of Ela's and Sera's (**Figure 2**). However, during the analysis, it was noriced that the pre-service teachers may express both positive and negative opinions that may be categorized as belonging to one of the contextual categories. For instance, a pre-service teacher may say: 'teacher-centered lessons may be preferable to avoid CM problems' (Ela) as opposed to 'I want to improve my CM skills because CM is important for effectiveness of teacher and her/his impact on student learning' (Melisa). Although both arguments are related to CM and the TSK, it is evident that the latter view is more supportive of a productive learning environment. As a result, it became clear that a pre-service teacher's contextual orientation cannot be determined by merely counting the contextual factors, but rather by considering the nature of these factors.

To compare and contrast these findings with those in the literature, it is found that all four pre-service teachers to be mostly preoccupied with micro-context elements with regards to Porras-Hernández and Salinas-Amescua (2013). This finding is supported with Swallow and Olofson (2017), who also found the micro-level factors to be most influential for TPACK enactment of (novice) teachers. However, micro-context contains a large number of elements from practical matters to teachers' beliefs and orientations. To this end, it is found that the explicit separation of practical matters from teachers' beliefs by Boschman et al. (2015) is critical for more detailed analysis. Using this scheme, the study revealed that the pre-service teachers with lower TPACK levels focused more on practical matters, whereas those with higher TPACK levels focused more on beliefs and attitudes.

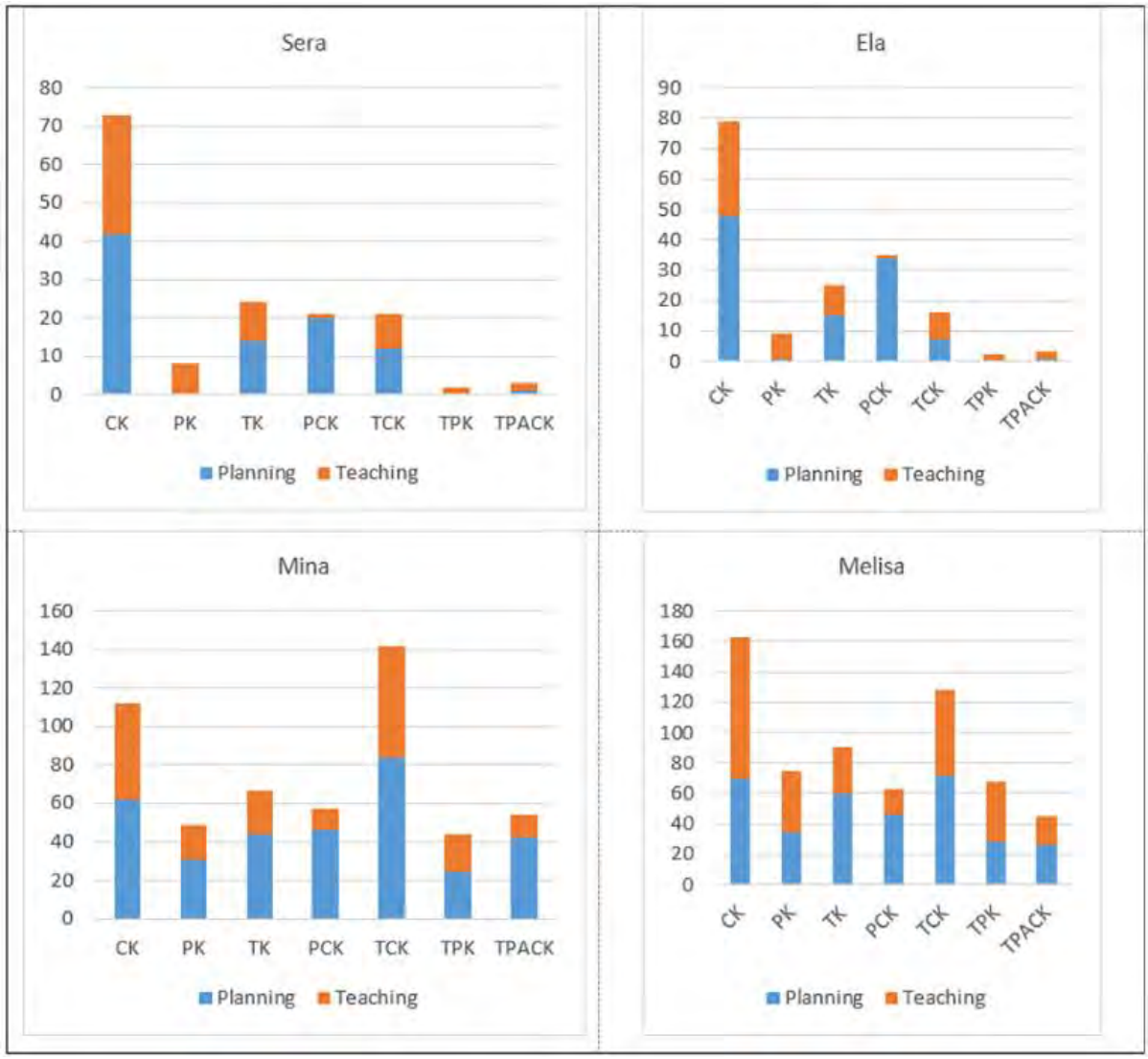

Figure 5. The comparison of observed TPACK domains between planning and teaching stages (solid lines represent the planning stage and dashed lines teaching stage) (Source: Author's own elaboration)

As for the demonstration of various TPACK levels, it is found that CK category was most readily demonstrated by all four pre-service teachers. This could be expected as content represents the main element that the teachers are expected to convey to their students. But in the process, which knowledge elements did the teachers most heavily draw upon? The findings here are two pronged due to the emergence of two types of pre-service teachers. Mina and Melisa, who both exhibited a higher awareness for TPACK, drew upon mostly their TCK knowledge. This was followed by relatively similar degrees of PK, TK, and TPK. Sera and Ela, who both exhibited a lesser TPACK awareness, exhibited similar levels of PK, TK, and TCK (all of which are less than those exhibited by Mina and Melisa). Furthermore, both pre-service teachers represented a very low degree of TPK. Most notably, it is found that the PCK levels of both groups of pre-service teachers were markedly low. As a whole, the blended PK domains (PCK, TPK, and TPACK) were the weakest for the lower achieving pre-service teachers. PCK was also lowest for the higher achieving group. TPACK and PCK were similar for both groups. The main difference between the two groups of pre-service teachers were in the TCK and TPK categories. The literature reports varying findings in these aspects. For example, by using a self-assessment instrument, Schmid et al. (2020) found that the mean CK score of 117 pre-service teachers was higher than their scores in other TPACK domains. Landry (2010) also found the CK of mathematics teachers to be higher than their other knowledge types. Most relatedly, Valtonen et al. (2019) found that development in PCK, PK, and TPACK domains go hand in hand. The development in CK and TK domains were found to be more isolated. These findings were closely matched by the current study. In other words, current study supports the notion that knowing technology and content alone, does not translate to high levels of TPACK. The pedagogical dimension and its combination with other dimensions appear to play a critical role.

The pre-service teachers with higher TPACK levels (Mina and Melissa) were more consistent in their TPACK between planning and teaching phases. Sera and Ela, who did not demonstrate TPACK and TPK skills during teaching, also did not show significant evidence of these domains in their planning artifacts. Furthermore, they also did not show notable presence in the PK domain as well. This finding supported that the PK domain is the most difficult to master and demonstrate among the core knowledge domains. Related conclusions have been reached by earlier studies. Chai et al. (2010) emphasized that PK has the largest impact on pre-service teachers' TPACK. Pamuk et al. (2015) and Schmid et al. (2020) found that TPACK is primarily influenced by TPK and

PCK. Dong et al. (2015) and Koh et al. (2013) also determined TPK to be a positive predictor of TPACK. Niess et al. (2006) observed that inexperienced teachers who had weaker pedagogical skills had more difficulty in blended knowledge domains. Most notably, Pierson (2001) stated that teachers that have low PK skills have difficulty in developing pedagogy-technology linkage even if they have high TK skills. This finding resonates strongly with current study as it is also found that Ela and Sera had low levels of TPK, despite both having higher TK skills.

There are several implications of these findings for teacher education. Many teacher education programs across the globe include at least one, or more, courses on teaching with technology (Han et al., 2017; Mouza et al., 2017; Starkey, 2020). These courses, however, do not generally consider the unique context that governs the participants' relationship with using technology for education. If teacher educators are aware of various contextual elements that may support or hinder the desired use of technology, corrections can be made early on. In the current study, two of the pre-service teachers predominantly used technology for time and CM. Other studies report similar usages of technology by novice teachers (Ertmer & Ottenbreit-Leftwich, 2010; Maddux & Johnson, 2006, Russell et al., 2003). This constitutes at least a part of their unique context. But just as it would be unreasonable for a doctor to use technology to "manage" patients, a teacher should not be doing the same to manage students. Technology should be used to get results and in the case of education, this usually means improved conceptual understanding. If pre-service teachers are openly exposed to such usages of technology and why it happens (i.e., the contexts that motivate these usages) during their undergraduate education, they may develop a higher tendency to use technology for correct purposes. The influence of pedagogy should also be clearly highlighted for using technology effectively. Similar to earlier work, current study found that combining PK with technological and CK is the most challenging part of the process. To remedy this, undergraduate level technology integration courses should always keep PK in the forefront. It should be made clear to teachers of the future that technology can only truly support teaching of a subject-matter if it is combined with sound pedagogical practices.

CONCLUSION

The ability to use technology for more effective teaching is a desired characteristic for many teachers of the current age (Otero et al., 2005). The current study aimed to provide a contextual lens by using the case of four pre-service mathematics teachers. To this end, three research questions were posed as explained in the Introduction section. Regarding the first research question, seven contextual factors that appeared to impact the TPACK enactment of these pre-service teachers were found. These factors which are reported in **Table 1** constitute one of the most important findings of the current study.

For the second research question, it is found that these contextual factors seemed to have a strong effect on the TPACK levels of these teachers. The two pre-service teachers who focus more on practical matters (CM and TM) appeared to be weaker in all core and blended TPACK domains compared to the other two teachers who put more emphasis on their beliefs and attitudes for teaching with technology. In other words, the focus on these different sets of factors appeared to strongly be related with the TPACK enactment of the teachers.

As for the third and final research question, the relationship between the TPACK levels during planning and teaching and whether this can be explained by contextual factors were investigated. Again, it is found that the pre-service teachers who put more emphasis on KOSs, TSK, ATT, and inquiry and EP to exhibit a more balanced distribution of TPACK levels for all knowledge domains during planning and teaching. On the other hand, the pre-service teachers who put more emphasis on classroom and TM exhibited a greater imbalance between planning and teaching.

As an additional observation, it was found that the core and blended knowledge domains that include PK appeared to be weaker compared to other knowledge domains, especially CK and TCK, which were found to be stronger. Within the confines of the current work, this suggests that pre-service teachers struggle mostly to incorporate pedagogy into their lessons. This highlights the need to give stronger emphasis to pedagogy in teacher training programs. By being cognizant of the contextual orientations of their students, teacher educators can find more effective ways to prepare the teachers of the future for teaching with technology. Future work can investigate whether openly discussing the effects of these contextual orientations with pre-service teachers can have a positive impact on their TPACK enactments.

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