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Elaboration of science teachers' technology-based lesson practices in terms of contextual factors influencing TPACK

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ABSTRACT

Background: One of the important elements of teachers' technology integration is Technological Pedagogical Content Knowledge (TPACK). Though there are studies on TPACK, limited information exists about its context element. This gap causes context-isolated studies for TPACK-related research.

Purpose: The aim of this research is to elaborate on science teachers' technology-based lesson practices in terms of contextual factors influencing TPACK.

Sample: The study participants consisted of 12 science teachers and 7 educational technologists by using snowball sampling.

Design and method: The case study design method was used in this study within the qualitative research paradigm. The data was collected with semi-structured interviews by following the protocol for strategic performance problems. The interviews were examined employing content analysis to reveal the themes.

Results and conclusions: The findings of the study indicated that TPACK is not only a stand-alone knowledge and skills, but also it is context-oriented. The multifaceted factors represent components of a multi-layered structure of the context. These factors can be perceived by the teachers at different levels according to school types. Furthermore, sub-themes of the contextual factors showed complex interrelationships. This study contributes to the literature by revealing the sub-themes of the context and in-depth examination of contextual factors suggested for future studies.

KEYWORDS

Technology integration; technological pedagogical content knowledge; context; science teachers; educational technologists

Introduction

Technology knowledge is one of the critical variables of technology integration (Karaca, Can and Yildirim 2013). Despite the high focus on the use of teachers' technological tools in the past, it seems that the integration of technology into the lessons and what technology can do for teachers in education is more important than mere use (Koehler and Mishra 2005). Therefore, over time, it was shifted from 'what' teachers need to know for using technology in education to 'how' teachers should use the technology, and this was conceptualized as 'Technological Pedagogical Content Knowledge (TPACK)' (Mishra and Koehler 2006). TPACK has a strong impact on teacher educational research (Harris

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et al. 2017; Mishra 2019). Playing a crucial role in the construction of technology integration, TPACK is not isolated from the school culture and the system, in other words, from the context (Mishra and Warr 2021; Warr, Mishra, and Scragg 2020). On the other hand, the importance of the concept of context is not yet well understood and so it is usually neglected in the studies, which is likely to cause misguidance and lack of support for effective teaching with technology in diverse learning settings (Rosenberg and Koehler 2015; Warr, Mishra, and Scragg 2020).

It is suggested that teachers' TPACK is situated in the context (Rosenberg and Koehler 2015). Furthermore, teachers' individual differences have an important role in their technology integration knowledge and skills. Therefore, it is necessary to delineate the teachers' situation, define the opportunities, and identify the stakeholders in the technology integration process to understand the TPACK practices. In the literature, there are some studies about the development of TPACK (Abbitt 2011; Koh 2019; Tai 2013), the relationships between some variables and TPACK (Kulaksız and Karaca, under review; Forssell, 2011; Kabakci-Yurdakul, 2018; Nelson, Voithofer, and Cheng 2019; Şimşek and Yazar 2018; Uslu 2018; Yerdelen-Damar, Boz, and Aydın-Günbatır 2017) and the definition and classification of the context in TPACK (Chai, Ling Koh, and Tsai 2013; Chai et al. 2014; Porras-Hernández and Salinas-Amescua 2013; Rosenberg and Koehler 2015). A situated understanding of technology integration can be a starting point for strategic moves to increase the actors' skills in the system, thus, relevant variables should be unveiled, and the relationships should be examined in detail to get a more in-depth comprehension. Therefore, this study aimed to take a close look at the contextual factors of TPACK in different school settings in the case of science education. In addition to the science teachers, this study took the perceptions of educational technologists to get a deeper understanding of the contextual factors influencing science teachers' TPACK during their technology-based lesson practices. This study is especially valuable in criticizing the individual and institutional differences about the contextual factors. The results of the study contribute to the related literature by uncovering and dissecting the common elements of context to improve teachers' TPACK and serve to expand and classify theoretical contextual TPACK frameworks.

Theoretical background

Technological Pedagogical Content Knowledge

Built upon Shulman's (1986) Pedagogical Content Knowledge (PCK), TPACK is described as knowledge of effective teaching with technology based on three knowledge domains as shown in Figure 1 (Koehler and Mishra 2005, 2009). TPACK consists of three basic components as Content Knowledge, Pedagogical Knowledge, and Technological Knowledge. Furthermore, Technological Content Knowledge, Technological Pedagogical Knowledge, and Pedagogical Content Knowledge emerge from their intersection points. Finally, the focal point in this framework is called 'Technological Pedagogical Content Knowledge'. TPACK provides a good theoretical basis for understanding teachers' technology usage practices in education (Porras-Hernández and Salinas-Amescua 2013). Its importance arises from approaching the technology

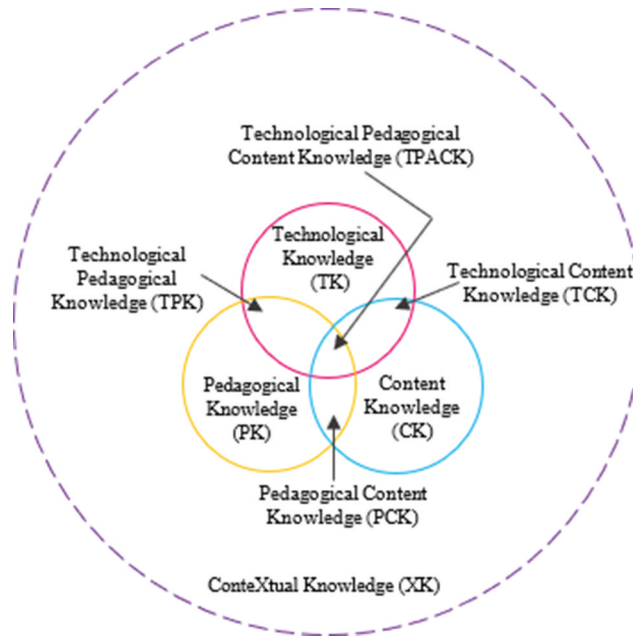


Figure 1. A revised version of the TPACK adapted from Mishra (2019)

integration process from a pedagogical perspective with the knowledge and skills of teachers in particular subjects. Koehler and Mishra (2005) emphasize that new concepts and representations emerge as a result of the inclusion of technology in teaching, rather than just adding technology to the existing pedagogy and content. Strengthening an effective technology integration, TPACK re-described how to teach with technology, which caused major changes in teacher education (Warr, Mishra, and Scragg 2020).

TPACK and context

The concept of context can contain variables related to the teaching environment, like student characteristics and readiness in a particular topic, teachers' technology attitudes, technological infrastructure in the school, financial issues, socio-economic level of teachers and students, school administration policies, school culture and atmosphere (Koehler and Mishra 2009; Porras-Hernández and Salinas-Amescua 2013; Rosenberg and Koehler 2015). However, it is seen that the concept of context is quite broad and situated in the studies, which causes inconsistencies in the definition of the context (Rosenberg and Koehler 2015). Besides its description, various theoretical models were proposed to illustrate the importance of the context in TPACK.

Chai, Ling Koh, and Tsai (2013) identified four interconnected contextual areas as a result of the literature review. While intrapersonal factors define teachers' pedagogical and epistemological beliefs; interpersonal factors define peer collaboration; institutional factors define the school as a cultural production area, and physical factors refer to technology access. Moreover,

they suggested, 'Technological Learning Content Knowledge' for students to describe how to learn with technology. Involving two key actors as teacher and student in the technology integration process, Porras-Hernández and Salinas-Amescua (2013) conceptualized and categorized the factors affecting TPACK in three contexts at the micro (in-class), meso (school), and macro (social) levels based on Bronfenbrenner's Ecological Approach. The micro-level includes expectations, beliefs, access to resources for instructional activities, teacher and student goals; the meso-level involves the attitudes of teachers, colleagues, students, parents, school administrators, and the conditions of the institution; and the macro-level expresses the social, political, economic, and technological conditions. As Chai et al. (2014) thought that more attention should be given to other actors in the educational system, they put forward an improved version of the model by Porras-Hernández and Salinas-Amescua (2013). According to the authors, the actors in the model can be students, instructional designers, department heads, school principals, ministry officials, software designers, parents, and industry partners, who contribute to or influence the continuum. The scope consists of five levels: 1) Micro as in-class factors affecting teachers instantly, 2) Meso as school-related factors involving teachers' environments and relations, 3) Exo as relationships with whom the teacher is closely but indirectly interacting, 4) Macro as social norms and national policies, 5) Chrono as a collective change of the teachers and society over time and its effects. Furthermore, Rosenberg and Koehler (2015) proposed a new representation by integrating the context in the TPACK framework developed by Porras-Hernández and Salinas-Amescua (2013). This new form covers the micro, meso, and macro levels with two actors as students and teachers. Teachers' TPACK and every element in the context have mutual relationships and the change of teachers' knowledge or the differentiation of relations between the stakeholders will cause chain changes in this technology integration system.

Moreover, Mishra (2019) put forward another reason for the lack of attention to the context that was not a knowledge area as other components of the framework. Therefore, the TPACK framework was upgraded by shifting from 'context' to 'contextual knowledge' (see Figure 1), defined as 'everything from a teacher's awareness of available technologies, to the teacher's knowledge of the school, district, state, or national policies they operate within' (p. 76). Lastly, it can be considered that the extensive definition and classification of the context proposed by Warr, Mishra, and Scragg (2020) as artifacts (devices, tools, etc.), processes (online management system, procedures, etc.), experiences (class meetings, online activities, etc.), systems (student support, services, budgets, etc.), and culture (perceptions of technology, schools, and education, etc.). Mishra and Warr (2021) indicated that these five spaces present new research paradigms and agendas for teacher education studies, rather than a conclusion of unspoken elements of context.

Based on previous studies, it is obvious that teachers' TPACK is influenced and directed by many factors. If the whole process is considered separately from the context, it is an indisputable fact that research results will be inadequate in explaining the phenomenon. Since the context in TPACK is complex and multi-level (Porras-Hernández and Salinas-Amescua 2013), investigation and elaboration of the context are required (Mishra and Warr 2021). In a previous study, the common contextual factors influencing science teachers' TPACK were found as student influence, teachers' attitudes and beliefs, technological infrastructure, administrative support, technical support, colleague interaction, lack of time, professional development, and educational technology experience (Kulaksız

and Karaca, under review). In this study, a path model was developed to investigate the interrelationships among these common contextual factors influencing the science teachers' TPACK. The results showed how suggested variables create complicated associations existing in Turkey context by highlighting the most critical factors as professional development and teacher beliefs and attitudes in improving TPACK. The current study took into consideration these uncovered contextual factors influencing science teachers' TPACK by Kulaksız and Karaca (under review) in order to elaborate on teachers' perceptions about each factor in technology-based science lesson practices from various perspectives. The first aim of the research is to bring out each participant's perceptions about the most critical contextual factors influencing science teachers' TPACK. The second purpose of the research is to show how the contextual factors influencing science teachers' TPACK vary by the school type.

Method

One of the qualitative research methods, the case study design method was used in this study as it allows researchers to reveal more in-depth findings on a specific topic (Miles and Huberman 1994). This approach employed in line with the research aimed to understand the teachers' technology-enhanced lessons from the point of influential contextual factors. The study was approved by the Educational Sciences Research and Publication Ethics Committee at Marmara University, Turkey (Approval Number: 2000/58662).

Participants of the study

The snowball sampling method was used to reach the people having expertise in technology integration. At the beginning of the study, one of the researchers attended an educational technology conference in İstanbul, Turkey, where teachers can present and share technology-related best practices. The researcher joined the sessions to observe the potential participants and then selected the participants who met the following criteria: minimum two years of teaching/educational technology experience, having necessary technological infrastructure at school, using technologies effectively in their lessons (for science teachers [ST]); giving in-service training on technology integration for STs (for educational technologists [ET]). The study group was extended based on teachers' recommendations accepted to contribute to the research. As a result, 12 STs (7 public, 5 private) and 7 ETs (2 public, 5 private) participated in the study (Table 1). The sample group consists of 8 males and 11 females. Their ages vary between 25–54 ($X = 34.89$; $Sd = 7.39$). Their teaching experience ranged from 2 to 23 years ($X = 10.37$, $Sd = 6.83$). Six participants have a master's degree and the others have a bachelor's degree. The interviews lasted for 40 minutes approximately.

Context of the study

Technology integration in Turkey has two main approaches in the aspects of public and private schools at the macro-level. First, the Movement of Enhancing Opportunities and Improving Technology (FATİH) Project was announced in 2010. After reaching a certain point in terms of technological infrastructure in the project (access, distribution, etc.),

Table 1. Demographics of the participants.

Participants	Gender	Age	Educational Level	School Type	Teaching Experience (Year)
S-1	Male	27	Graduate	Public	5
S-2	Female	25	Graduate	Private	2
S-3	Female	35	Graduate	Public	12
S-4	Male	54	Graduate	Public	23
S-5	Male	40	Graduate	Public	17
S-6	Male	37	Master	Public	7
S-7	Female	39	Graduate	Public	15
S-8	Female	42	Graduate	Public	19
S-9	Male	32	Graduate	Private	11
S-10	Female	28	Graduate	Private	5
S-11	Female	40	Graduate	Private	8
S-12	Female	29	Graduate	Private	5
E-1	Male	30	Master	Private	2
E-2	Male	27	Graduate	Private	3
E-3	Female	37	Master	Private	14
E-4	Female	37	Master	Private	15
E-5	Female	44	Master	Private	22
E-6	Male	33	Master	Public	10
E-7	Female	27	Graduate	Public	2

some pedagogy-based steps (professional development training such as seminars, and workshops) were started due to teachers' low-level technology integration skills and practices. Furthermore, Information Technology Counselors [ITC] were employed in the schools to sustain both technological infrastructure maintenance and teachers' technology integration skills development at the meso-level. Some of ITC's duties are to conduct activities for teachers to use technological tools and materials in education effectively, provide technical assistance, deliver up-to-date information about educational technologies, and guide subject teachers about instructional technologies (such as choosing appropriate digital materials, adapting technology into lesson plans, etc.). They are also supportive of the technology skills of the students with various activities, as ITCs also work as information technology teachers in public schools.

Second, different projects such as 1:1 Tablet, Bring Your Device, Teach Free Day were implemented in private schools earlier than in public schools at the meso-level. Generally, technical updates in private schools are supported by the IT units. Techno-pedagogical services are provided to the teachers by the educational technology departments. Some of these services involve curriculum planning with subject teachers, training about instructional technologies periodically, facilitating subject teachers' technology integration implementations as well as delivering instruction to the students to enhance their digital competencies. In some schools, there is no educational technology unit, however, these kinds of support are provided by computer science teachers.

Although people who provide educational technology support were called by various names in different school types, they are mentioned as educational technologists in this study. Consequently, being one of the key actors in the technology integration process, educational technologists are responsible to guide and facilitate both the teachers' and students' progress at the school level. Therefore, within the scope of the aforementioned duties, it is seen that ETs and STs are in a close relationship at the school regarding technology use in education. Furthermore, being one of the best observers of subject teachers' technology-based lesson practices makes the ETs an important information

source for that issue. As a result, both ETs, the main supporter and observers of science teachers' technology-based lesson practices, and STs who personally experienced these practices were included in the current research.

Instrument development and interviewing

The data was collected through semi-structured interviews, which allows the participants to express themselves more easily, and allows the researchers to get more in-depth answers (Büyüköztürk et al. 2014). Semi-structured interview forms for ETs and STs were developed by the researchers based on the protocol for strategic performance problems suggested by Jonassen (2011) as lesson-planned-manner within the scope of the study. Since real pedagogy problems are poorly structured, complex, and have more than one answer (Koehler and Mishra 2005), the teaching process is included in the strategic performance problems group, which can be defined as critical decision-making processes (Jonassen 2011). Thus, Critical Decision Method was used by following a four-step procedure: 1) Eliciting an incident: The interviewer starts with an opening question towards the study purpose. 2) Timeline verification and decision point identification: The researcher tries to sort and divide the information shared by the participant by a timeline. 3) Progressive deepening: The researcher takes the participant back to the critical points with the probes to obtain detailed, comparative, and field-specific data. 4) 'What if?': This strategy allows the participant to reconsider the situation from different or external perspectives in depth. Consequently, the initial forms were revised based on the feedback of two experts from the Computer Education and Instructional Technologies, and Science Education departments. The final form included three main questions, and some probes to reach more detailed answers (Patton 2002).

Before the meeting, the participants were informed about the interview content, researchers' identities, confidentiality, privacy, and volunteering to create a bridge of trust. The appointments were scheduled for suitable places and times. Earlier in the interview, a general talk about education was used as an icebreaker until they feel comfortable to start. Each participant was asked for their consent about recording interviews. In the first two questions, participants were asked to introduce themselves and their schools which allowed the researcher to take notes about potential contextual factors. In the third question, STs were asked to share their experiences regarding the whole teaching process (lesson preparation and implementation, after lesson work) of a technology-based example lesson without the researcher's intervention. After having each of the participants' stories, the researcher briefly re-expressed their talks to verify, and note the critical points, and sorted them by the chronological flow. Afterwards, each relevant part of the process was reminded by using the participant's expressions, and probes such as 'What is done at this stage?', 'How do you do this?'. Finally, the interview was completed by asking whether teachers received any positive or negative feedback from the stakeholders in the process (colleagues, school administration, parents, students). Meanwhile, in the third question for ETs, they described the activities conducted in their schools in the context of educational technology. Afterwards, probes were used

Table 2. Final Code List.

Themes (Factors)	Sub-themes (Sub-factors)
Technological Infrastructure	Technological infrastructure and access, Digital material
Technical Support	Technical support for technological infrastructure, Instant technical support, Educational technology support
Administrative Support	Administrative encouragement/obligation, School vision, Curriculum, Technology integration policy
Professional Development	In-school, Out of school, General
Lack of Time	Lesson preparation, Intensive curriculum, Time management in class, Learning instructional technology
Teachers' Attitudes and Beliefs	Attitude, Anxiety, Usefulness, Easiness, Intrinsic motivation, Technology interest, Technology perception, General
Educational Technology Experience	
Students' Influence	Students' profile, Students' technology attitude, Students' readiness and needs, Students' feedback, Students' technology usage level, Students' socioeconomic level, Students' technology access from house
Colleague Interaction	Communication, Sharing, Interdisciplinary studies, Negative effects

for each activity. The interviews were completed by asking whether each activity was separately effective in improving the teachers' TPACK and what the influencing factors were. The interviews continued until the data saturation was reached.

Data analysis

The interviews were transcribed, coded, and content analysis was used to examine the qualitative data in terms of words and themes to determine and make sense (Patton 2002). Miles and Huberman (1994) recommendations were taken into consideration for the analysis. First, the literature was reviewed for a preliminary list of contextual factors. In the early stages of the analysis, an inductive approach was used to reveal potential themes and categories while developing a codebook (Patton 2002). All the interview transcripts were encoded line by line, and new codes were added. Second, the first code list was conceptualized. While determining the codes, it was observed that the factors at the classroom level were in close interaction with the teachers' TPACK. TPACK framework (Koehler and Mishra 2005; Mishra and Koehler 2006) was taken as a reference point for the exclusion. The data was analyzed for a second time according to the updated code list. Third, each theme representing a factor with its sub-themes was named and defined based on a final code list (Table 2). Fourth, one random file from each interview group was analyzed independently by a second researcher for intercoder reliability. There was 85.18% agreement for ETs' interviews, and the agreement for STs' interviews was 92.85%, which was evaluated as satisfactory (Miles and Huberman 1994). Finally, the interview transcripts were revised by considering opinion differences between the coders.

Findings

The frequencies and percentages of contextual factors were calculated for each of the participants and school types. In Table 3, the themes are presented based on total frequencies ($f = 868$) and two types of school context as public ($f = 521$) and private ($f = 347$). As shown in Table 3, in public schools, it was seen that the most

Table 3. Contextual factors by school type.

Factor	Public		Private		Total	
	f	%	f	%	f	%
Student influence	84	24.21	87	16.7	171	19.7
Teachers' attitudes and beliefs	71	20.46	99	19	170	19.59
Technological infrastructure	76	21.90	45	8.64	121	13.94
Administrative Support	24	6.92	89	17.08	113	13.02
Technical support	39	11.24	37	7.1	76	8.76
Colleague interaction	11	3.17	62	11.9	73	8.41
Lack of time	17	4.9	41	7.87	58	6.68
Professional development	14	4.03	39	7.49	53	6.11
Educational technology experience	11	3.17	22	4.22	33	3.8
Total	347	100	521	100	868	100

important factors influencing teachers' TPACK were found as students' influence ($f = 84$, 24.21%), technological infrastructure ($f = 76$, 21.90%), teachers' beliefs and attitudes ($f = 71$, 20.46%), technical support ($f = 39$, 11.24%), and administrative support ($f = 24$, 6.92%) respectively. In private schools, the most important factors were found as teachers' beliefs and attitudes ($f = 99$, 19%), administrative support ($f = 89$, 17.08%), students' influence ($f = 87$, 16.7%), colleague interaction ($f = 62$, 11.9%), and technological infrastructure ($f = 45$, 8.64%) respectively. In total, the most important factors influencing teachers' TPACK were found as students' influence, teachers' attitudes and beliefs, and administrative support. Furthermore, [Table 4](#) shows the most critical factor(s) perceived by each participant. Conspicuously, these factors constitute approximately one-third of the frequencies mentioned in their interviews for almost all teachers. Differences between frequencies are considered to demonstrate the importance level of the factors for teachers in different contexts. All themes are explained with examples from interviews in the following parts.

Student influence

As shown in [Table 3](#), among all the factors, the most critical factor for STs' TPACK is the student influence in terms of total frequency (19.7%, $f = 171$). While it is the most dominant factor (24.21%, $f = 84$) in public schools, it is the third most important factor in private schools (16.70%, $f = 87$). It is crucial for seven STs according to [Table 4](#). However, the basic characteristics of the students are similar in both school types. Even though a wide range of the participants' demographics, all of them reached a consensus about the new student profile, in which they described students as '21st-century students', 'new generation', or 'Z generation'. S-1 exemplifies this profile: 'How

Table 4. The most critical contextual factors of participants based on their interview code frequencies.

Participants	The most critical factor(s) for each participant	Total code frequency*
S-1	Student Influence ($f = 20$)	58
S-2	Teachers' Attitudes and Beliefs ($f = 11$)	34
S-3	Technological Instructure ($f = 8$), Student Influence ($f = 8$)	34
S-4	Technological Instructure ($f = 8$), Student Influence ($f = 8$)	23
S-5	Student Influence ($f = 11$)	45
S-6	Student Influence ($f = 10$)	35
S-7	Technical Support ($F = 5$), Teachers' Attitudes and Beliefs ($f = 5$)	25
S-8	Teachers' Attitudes and Beliefs ($f = 17$)	63
S-9	Teachers' Attitudes and Beliefs ($f = 24$)	96
S-10	Student Influence ($f = 17$)	62
S-11	Administrative Support ($f = 8$), Lack of Time ($f = 8$)	36
S-12	Student Influence ($f = 22$)	75
E-1	Administrative Support ($f = 12$)	40
E-2	Administrative Support ($f = 15$)	53
E-3	Administrative Support ($f = 7$), Teachers' Attitudes and Beliefs ($f = 7$)	32
E-4	Teachers' Attitudes and Beliefs ($f = 11$), Colleague Interaction ($f = 11$)	67
E-5	Technical Support ($f = 13$)	45
E-6	Technological Instructure ($f = 7$)	23
E-7	Technical Support ($f = 14$)	58

* Each participants' total code numbers revealed from their interview

many children are sitting and reading a book? But every child follows Youtubers. So, they all have something to follow. Children like to watch more now. Now, reading is out of fashion, unfortunately'. This new student profile, their technology attitudes, skills, and demands lead STs to seek and acquire different skills to integrate technology in education effectively. Therefore, STs stated that it is an inevitable transition from PCK to TPACK.

Students' profiles are also shaped around students' subject readiness, technology usage levels, and access to digital materials from home, which direct the findings compare in terms of the school types. In public schools, students with a high level of technological skills support their teachers as in-class technical assistants, especially when STs first meet with technology integration. Meanwhile, the consequences of the students' profile heterogeneity can cause technical problems due to the misuse of technological devices. In addition, students' socioeconomic levels and technology access from home can interrupt both in-class and extracurricular practices of STs. Contrary to private schools, STs do not encounter these limitations due to the students' high level of technological skills, access to technology, and socioeconomic levels. As a result, differences in student profiles and opportunities guide, motivate and/or interrupt STs to develop TPACK and discover alternative technology-enhanced lesson implementations.

Teachers' attitudes and beliefs

The second important factor on STs' TPACK is their attitudes and beliefs (19.59%, $f = 170$). Although teachers' attitudes and beliefs are the most important factor (19%, $f = 99$) in private schools, it is the third most important factor (20.46%, $f = 71$) for public schools. No major difference was seen by the school type. This factor was found vital for four STs and two ETs. Teachers' attitudes can occur as a filter or an amplifier toward TPACK. The STs' beliefs and attitudes were generally positive; however, negative views were mostly voiced by ETs putting efforts to overcome this barrier.

Teachers' technology interests and motivations seem crucial to cultivating positive attitudes regarding TPACK. In-depth results showed that one of the reasons behind their interest was the easiness and usefulness of instructional technologies. S-6 says: 'It makes classroom management easier. Discipline problems are getting less'. Also, it provides solutions to the lack of materials in the laboratory. Visualization and memorability of the digital contents for students encourage the STs to select appropriate technologies. Furthermore, the participants state that it will be difficult to achieve some learning outcomes in technology-free lessons. On the other hand, teachers with negative attitudes towards instructional technologies were characterized by participants as 'anxious', 'hesitant', 'prejudiced', and 'do not believe in the benefits of technology'. S-9 says that some colleagues think integrating technology in education is a 'waste of time'. ETs appreciate positive attitudes, meanwhile, they help teachers with negative attitudes to gain experience with professional development activities and technical support. E-5 says: 'When you eliminate teachers' unknowns, worries, and anxieties, they are not afraid of change'. However, ETs sound desperate to change the attitudes of 'silent' or 'older' teachers like E-3: 'You cannot break that wall'. As a result, teachers' beliefs and attitudes seem crucial due to being preconditions to develop TPACK.

Technological infrastructure

The third substantial factor on STs' TPACK is technological infrastructure (13.94%, $f = 121$). This is the fifth most important factor in private schools (8.64%, $f = 45$). On the other hand, it is revealed as the second most important factor for public schools (21.90%, $f = 76$). This theme was revealed as the most substantial factor for two STs and one ET from public schools. The findings indicated that technological infrastructure and accessibility are mentioned as fundamental elements for technology integration. However, participants have different infrastructure descriptions, the perception of 'adequacy' of the infrastructure by teachers varies according to school type.

Although technology description was mostly limited to smartboards and the internet in public schools, STs usually mentioned that these two were 'sufficient' and considered as an alternative for eliminating other educational and physical inadequacies. Solely, the devices out of operation negatively affect STs' TPACK practices. Therefore, STs try to solve this problem by transforming technology-enriched lessons into technology-free lessons. On the contrary, even though most private schools have broader facilities including labs, tablets, software, STs express them as 'insufficient' because of the access. The problems usually arise from the number of devices, usage frequencies by other teachers, and not having updated versions of the technology. Unlike public schools, private school teachers develop alternatives not from digital to traditional, but from digital-to-digital lessons. For example, when S-2 prepares a lesson plan for a STEM (Science, Technology, Engineering, Math) activity, interface differences cause problems, and a solution comes up with: 'While applying in my school, we integrated Arduino into our system since there is no temperature sensor with LEGO sets'. Furthermore, while all teachers highlighted that free digital material access is vital in both types of school, ETs also pointed out it as encouraging. The findings show that the technological facilities, which are a reflection of the technology integration policies of the school administration, are effective on STs' TPACK in various ways through motivation and collegial interaction.

Administrative support

The fourth effective factor on STs' TPACK is administrative support (13.02%, $f = 113$). While this is the fifth most important factor in public schools (6.92%, $f = 24$), it was revealed as the second most important factor in private schools (17.08%, $f = 89$). It occurred as the most significant factor for one ST and three ETs from private schools. It was observed that school educational vision guides technology integration planning, practices, and preferences. However, the interesting point mentioned by all participants is that students are prohibited from using mobile in schools. Most of the teachers expressed that this is a contradiction of policies because of limiting the technological opportunities. The administration's support and decisions are perceived as a necessity or pressure according to teachers' attitudes and beliefs.

The study results indicated that the administrative support in public schools is generally just limited to the FATİH project in terms of the vision and policies. The curriculum is not compatible with the technology and sufficient material is not provided, which directly affects teachers' practices. Most of the participants said that the verbal encouragement of principals to teachers is weak and insufficient about technology integration. When

teachers with high motivation demand support from the principals, they complained about unmet requests. Besides, since administration in private schools emphasizes innovation and technology as mentioned by participants, technology integration projects are implemented in schools, technological infrastructure is improved accordingly, and the curriculum is periodically updated by teachers. Therefore, E-1 marked that showing a high level of TPACK becomes a necessity to be hired due to the school's technological infrastructure in private schools. Teachers are encouraged by the administration to keep up with the new curriculum to follow the 'new system'. New requests of principals can also be perceived as an obligation like the S-11 case: 'When the administration makes it necessary, we become creative. Because we have to'. Administration not only directs teachers to develop their TPACK but also organizes the content of information technology courses to support students' digital competencies. Thus, individuals' needs are brought together by the administration in the technology integration studies, and they complement each other like puzzle pieces. E-4 admits that 'the competition' among the private schools creates this digital transformation pressure. As a result, while there is a diversity in implementation among the private schools and they are very demanding towards teachers like participating in various activities such as conferences, projects, and curriculum updates; public schools are more centralized in terms of application of the technology integration and curriculum updates because of being part of nationwide FATİH Project and the principals have lower impacts on the teachers.

Technical support

The fifth important factor on STs' TPACK is found as technical support (8.76%, $f = 76$). While this theme was the fourth important factor in public schools (11.24%, $f = 39$), it was the seventh important factor in private schools (7.1%, $f = 37$). It was revealed as the most critical factor for one ST and two ETs. The results of interviews show that the support demanded by teachers in public schools from ITCs is purely technology-oriented, while in private schools this support differs in the context of technology and pedagogy, which is offered by different units.

In public schools, STs firstly try to solve the technological problems by themselves. They usually forward their instant technical support requests via WhatsApp groups to ITCs. Contrary, teachers do not seek any educational technology support such as teaching techniques, guidance, instructional design, digital material development. E-7 states that not providing educational technology support to stakeholders of the FATİH Project causes missed opportunities and remain them abandoned of the technological infrastructure. Again, in most private schools, IT and educational technology support are provided sufficiently by two separate units most of the time. Educational technology support requests are usually about digital material access and development, curriculum studies, and training (seminar, workshop, etc.). E-3 stated that she provides educational technology support individually for STs who are not able to integrate technology into education. Furthermore, they guide teachers' first lesson experiences about new tools/applications, which helps to relieve their anxieties and facilitate their TPACK skills acquisition. It is seen by ETs that this support decreases over time as the STs' TPACK increases. Considering the activities carried out, ETs provide more sophisticated support for teachers' TPACK development, which is linked with professional development.

Colleague interaction

The sixth factor on STs' TPACK is colleague interaction (8.41%, $f = 73$). Surprisingly, there are considerable differences between school types. While it was the fourth most important factor for participants from private schools (11.9%, $f = 62$), it was considered one of the least important factors for public schools (3.17%, $f = 11$). As stated under the administrative support theme, teachers in public schools work more independently in teaching activities than in private schools. Teachers in public schools act together in activities that require shared timings such as exam-course schedules, laboratory usage, and sharing materials. Interestingly, experience exchange or collaborative work on technology integration is quite limited. Instead, there are negative effects of other teachers on the one who is good at technology integration like S-8: 'To be honest, when I share my technology-related experiences, I don't get a very positive reaction from my colleagues'. The study results indicated that unsupported teachers generally seek help from teachers in other schools.

In private schools, the common hours of teacher groups were defined as 'very precious' sharing time for the development of lesson plans and materials, and experience exchange. They highlighted that they share what they learned and heard, even though they do not always have the opportunity to try it. Also, all participants indicated that interdisciplinary studies strengthen the relationships between the teachers, and not only reveal the skills that teachers need to develop, but also motivate them to work effectively. For example, S-2 said: 'It was really difficult for me to plan an interdisciplinary lesson. I got support from an IT teacher on how to do it as I was not feeling enough on my own'. When S-9's new ideas were supported by the administration, his colleagues were not enthusiastic to learn and their reactions are generally liked as 'There will be an extra job for us'. As a result, colleagues' negative effects are common in both school types. On the other hand, teachers with positive attitudes towards technology integration were stated to share their digital materials, technology-enhanced lesson plans, etc. on the internet and in the school with their colleagues.

Lack of time

The seventh important factor influencing teachers' TPACK was lack of time (6.68%, $f = 58$). This theme was mentioned more by participants in private schools (7.87%, $f = 41$) than in public schools (4.9%, $f = 17$). Also, it was the most important factor for one private school ST. Although the teachers' opinions about time usually do not differ by school type about preparation and time management for technology-based lessons, limited time for learning instructional technology and intensive curriculum sub-themes differ among the teachers in private schools.

For example, S-11 complained about lack of time because of feeling stressed. ETs also justify teachers by referring to their workload because of intense curriculum pressure. Then, E-4 emphasized the importance of time for learning and preparation: 'The teacher must have time to search. They will research, apply it in the lessons, get feedback and so on'. The time management in technology-based lessons varies depending on the teachers' TPACK levels and educational technology experiences due to the difference between plans and implementations. However, some teachers stated that instructional

technologies can also offer alternatives and facilities to the intense curriculum pressure as S-5 mentioned: 'We do a lot of work in a short time. Now, the children understand what the photosynthesis experiment is in 10 minutes. You can even look at a second experiment or discuss questions'. Participants suggested subjects in the curriculum, the materials, and the lesson plans must perfectly match in terms of timing. Also, time allocation is required to be parallel with the professional development level of the teachers.

Professional development

The eighth important factor was professional development (6.11%, $f = 53$). This theme was voiced both by participants in public schools (4.03%, $f = 14$) and by participants in private schools (7.49%, $f = 39$). Teachers working in public schools mainly talk about in-service training as professional development. However, the majority of teachers working in private schools talked about all the in-service, external, and individual attempts for their TPACK as professional development. Therefore, professional development can differ by school type.

A few teachers with self-awareness and high motivation in public schools mentioned studying for TPACK development personally. S-6 expresses the lack of knowledge and skills by complaining about poorly designed in-service training and suggests university-school cooperation as a solution not only for himself but also on behalf of other teachers in the school. On the other hand, professional development activities in private schools vary as to whether or how the school administration supports in-service training. S-2 refers critical role of the training: 'The seminars I attended are very effective. The activities affected me a lot and I think that I should apply this in my school, I should use it in my lessons'. However, she considered that it is hard to continue without school support because of financial difficulties. Therefore, S-9 focused on his efforts to improve TPACK by allocating time for learning new educational software on the internet. Findings show that teachers' sustainable professional development seems related to both administrative support and their willingness. All participants believe that teachers have a critical role in strengthening their TPACK when adequate opportunities and practice-based professional development are provided. The teachers also emphasized that online professional development networks are undeniably useful.

Educational technology experience

The least important theme is teachers' educational technology experience in total with the rate of 3.8% ($f = 33$), a rate of 3.17% ($f = 11$) in public schools, and a rate of 4.22% ($f = 22$) in private schools. Results show that teachers' mental schemas linking TPACK knowledge and skills were formed during the technology-based lessons. As stated by S-9, even though teachers had some problems at the beginning, as educational technology experience increases, they perform successful technology-based lessons by acquiring necessary TPACK skills. This experience helps teachers to have high self-efficacy and self-regulation processes in this field to make successful progress. Also, E-1 confirms that in-service training with the same content was mandatory every year in the past, however, nowadays they demand only necessary courses because teachers get more competent

over time. ETs' observations about changes in professional development constitute proof about as teachers' instructional technology experiences to be deepened. Every other day, they gain more knowledge and reach more implementation areas. Therefore, the experience was considered an opportunity linked to the theory and practice of TPACK and seemed directly related to teachers' attitudes and professional development.

Discussion and Implications

A case study was conducted to elaborate on science teachers' technology-based lesson practices in terms of contextual factors revealed influencing TPACK by Kulaksız and Karaca's (under review) study, involving student influence, teachers' attitudes, and beliefs, technological infrastructure, administrative support, technical support, colleague interaction, lack of time, professional development, educational technology experience. For this aim, teachers' perceptions about each factor were explored in different practice contexts of public and private schools. According to the study results, in public schools, it was seen the most important factors influencing teachers' TPACK were found to students' influence, technological infrastructure, teachers' beliefs and attitudes respectively. It was somehow different for private schools as the most important factors were teachers' attitudes and beliefs, administrative support, and students' influence respectively. Accordingly, the main difference between public and private schools was about technological infrastructure and administrative support and it might be an indication of public schools' requirements for technological infrastructure and private schools' demands for administrative support to integrate technologies into school settings. It is not a surprising result as the private schools in Turkey have more opportunities with respect to technological infrastructure, and the administrators are generally more supportive of teachers' technology use. As the FATİH project has been criticized for not providing teachers with enough techno-pedagogical training and subject-specific digital materials (Bozkuş and Karacabey 2019), the study results suggest that public schools should guarantee in-service training, technical support, access and availability of necessary digital media and technological infrastructure opportunities. The study findings further indicated that students' influence and teachers' attitudes and beliefs were common important factors in both private and public school settings and so, special attention should be given to these key factors.

Students are not only stakeholders in the technology-based lesson practices but also the most influential actors on teachers' TPACK. The results clearly show that factors such as students' subject readiness, profile, technology usage levels and attitudes, and access to technology from home also guide teachers' technology integration. Furthermore, some students directly boost teachers' TPACK by providing technical support. Thus, it can be said that one of the reasons affecting teachers' beliefs and practices regarding technology integration is the new generation called 21st-century students (Ertmer et al. 2012). Born in an environment of rapid technological inventions, 21st-century students' high expectations are likely to push today's teachers to use technologies effectively in their lessons. Even though students are included as actors in TPACK contextual models (Porrás-Hernández and Salinas-Amescua 2013; Rosenberg and Koehler 2015), there are few studies in the literature that include the effects of students on teachers' TPACK. Thus,

future studies should focus on investigating how different features of today's students' profiles change teachers' decision mechanisms, lesson plans, and in/out-class activities in the technology integration process.

Teachers' beliefs and attitudes towards educational technology are a filter that might be perceived both as a disincentive or incentive for technology integration (Ertmer et al. 2012). On the one hand, teachers with positive attitudes think that technology increases students' motivation and facilitates educational activities. Therefore, they participate in professional development activities to improve their TPACK and share what they learned with their colleagues. On the other hand, teachers having negative thoughts are afraid of and avoid the use of technologies. Moreover, since they have judgments about whether technology is destructive to education or it is not necessary, they do not participate in professional development activities or do not adopt these competencies. Since teachers' beliefs and attitudes towards educational technology are a change-resistant precondition for TPACK, some interventions should be taken by policymakers or schools/department heads. Such strategies as promotion, appreciation, and exemplary lesson presentations can help to shift their ideas. Also, long-term professional development strategies should be carried out to persuade teachers to find out alternative ways. Based on the study results, it is suggested that teachers with positive attitudes can be ambassadors for an innovative school environment and strategies can be researched in this regard.

The results further indicate that technological infrastructure is essential, however, its existence does not guarantee its acceptance by all teachers. Teachers with high TPACK constantly need new digital materials and resources, so they generally describe school facilities as partially inadequate. Moreover, technical and pedagogical support plays a mediating role to learn, use effectively, and disseminate resources. Indeed, expert assistance facilitates the professional development training and lesson design activities for technology integration (Kafyulilo, Fisser, and Voogt 2015; Koh and Chai 2014). Thus, the necessary support mechanisms in line with the school's vision should be provided for teachers and students. Additionally, the student-teacher/device ratio and usage schedules should be adjusted well to use the existing resources efficiently.

The study findings further indicated that administrative support emerged as an important factor for TPACK, and the most important factor for some teachers in this study. Findings indicated that administration as a multidimensional structure has various direct and indirect effects within the school's technology integration system via its sub-themes. For instance, school leadership can increase teachers' technology use (Mishnick 2017) and professional development (Evers, Van der Heijden, and Kreijns 2016; McPheron 2019), as the school administration is responsible for the implementation of the technology integration policies. Instead, they should provide the necessary professional development training, create support mechanisms, and purchase equipment. While the competitive environment among private schools leads them to integrate technology into their vision and advance these competencies, unfortunately, administrators in public schools have difficulties in finding a determination in the use of technology due to financial impossibilities (Hacıfazlıoğlu, Karadeniz, and Dalgıç 2010). To do so, school principals should make a claim for their role as technology leaders, who should comprehend technology integration at the macro-level and get insights on the meso-level to determine the school's policies.

Colleagues' interrelationships in the schools are usually shaped around curriculum development meetings, sharing digital materials and lesson plans. Such interdisciplinary studies and technological infrastructure lead teachers to increase their TPACK. Besides, teachers are influenced by their colleagues' representative in-class practices and achievements through the discourses of students and administrators. This effect is perceived as a pressure on teachers with negative attitudes and reveals another important result of the study. The source of negative interactions among colleagues stems from teachers' unwillingness to leave their comfort zone. For example, in Turkey, teachers in private schools renew themselves and participate in professional development activities because of being afraid of losing their jobs, while teachers in public schools attend in-service training just because of obligations (Pala 2019). However, positive teachers influence each other's TPACK in various ways such as attendance at professional development activities, experience exchange, and guidance/mentoring. Hence, it is recommended that professional development activities including collaboration, coaching, and expert support should be implemented by the institutions (Darling-Hammond, Hylar, and Gardner 2017). Besides, sustainable individual professional development of teachers can be economically challenging without school support. Since teachers do not work under equal conditions, and their needs and expectations are not the same, they need training in different contents, methods, and contexts. Therefore, the school administrators should organize context-sensitive, practical, and needs-oriented professional development programs to expand teachers' TPACK and promote a collaborative working environment. Furthermore, to integrate the professional development of teachers into school reform, it is recommended that teachers take an active role, have dynamic relationships, and consider professional development as a variable and ongoing cycle as a part of the school reform (Imants and Van der Wal 2020). It is suggested to consider these features in in-service training to be planned for TPACK development and to test their effectiveness. Future studies should focus on how to develop a sustainable and comprehensive TPACK professional development model.

Furthermore, the study findings shed light on how the factors vary for different persons and for different school types. Accounting for the school type, it can be concluded that each school progresses according to its own dynamics and organizational culture. The factors that emerged in this research can help to demonstrate the functioning of the technology integration mechanisms for both public and private schools. The results of this study may be helpful in explaining the reasons behind resistance to change and not working strategies in both kinds of school environments. In future studies, it seems vital to define the working environment as detailed as possible.

In addition to revealing the factors affecting teachers' TPACK for different school types, the study findings point to the importance of considering the context holistically to see the entire picture of the system. Thusly, it was found that the themes that appeared in this study might be evaluated at two levels as micro and meso. While the micro-level contained student influence, teachers' beliefs and attitudes, and educational technology experience; the meso-level was considered as colleague interaction, professional development, administrative support, technological infrastructure, and technical support. However, the mentioned factors can be interpreted at different importance levels according to some sub-dimensions and school types. For instance, although the science curriculum is centralized at the macro-level in Turkey, it might be classified under school

administration at the meso level in this study because of the diversifying implementations in the schools. Also, the curriculum can be defined as a macro or meso-level factor in different research contexts. The time factor is another example that its existence can be seen at all levels because of influencing both people and practices in the classroom or school. The study findings might present a guide for controlling, and classifying the contextual variables in future studies. The contextual factors should be examined in-depth by using some qualitative and experimental research methods, which would help to reveal different classifications.

The study findings provide evidence for which factors are most influential on science teachers' TPACK, why, and how. People's perceptions indicate that they form their own sui generis reality and the context proves to be unique both to the person and to the institution. This might explain the failure of previous technology integration projects and implementation strategies and so it would be a good idea to develop and implement some strategies considering both the institutions' dynamics and individual teachers' varying needs. This study would enlighten how to design such technology integration projects and school-based implementations. As this study was carried out in schools in the Turkish education system in the field of science education, future studies should examine TPACK's contextual variables in different countries and/or in different disciplines including multiple actors.

Conclusion

It was concluded that these factors may not be effective at the same rates in the context of each school type, even though they may show differences for each individual. Since this diversity creates an environment containing different parameters, the context proves to be unique to the person and the institution. TPACK is context-oriented, and these contextual factors represent components of a multi-layered structure. In conclusion, though it is not easy to classify the contextual variables and turn them into procedural knowledge to integrate the teachers' contextual knowledge, the results of this study contribute to the literature by revealing and extending the context's sub-dimensions in terms of school types and teachers' perceptions.

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