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A Meta-Synthesis Research on Knowledge of Pre- and In-Service Science Teachers in Turkey*

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ABSTRACT

This research aims to analyses qualitative/mixed studies done between 2015 and 2019 on the knowledge of pre- and in-service science teachers in Turkey. For this meta-synthesis research, 10 Master's and 10 PhD theses, which are available in the archives of Higher Education Council National Thesis Centre, and two full-text articles published in the journals indexed in Google Scholar provided the data. In this research, the contents of these theses and articles are analyzed and synthesized in depth. Results revealed mixed method was mostly used in the studies selected, participants of the studies were mostly pre-service science teachers, the studies especially put more focus on the "technological pedagogical content knowledge" of the pre- and in-service science teachers, and the studies discussed mostly the knowledge levels of pre- and in-service science teachers. The findings of this meta-synthesis call for future qualitative studies which examine the growth of in-service science teachers' "technological pedagogical content knowledge" in particular as well as the level and development of other types of knowledge ("curriculum knowledge", "knowledge of learners and their characteristics", "knowledge of educational contexts", "knowledge of educational ends, purposes, and values and their philosophical and historical grounds", "technological knowledge", "technological content knowledge", and "technological pedagogical knowledge") of pre- and in-service science teachers.

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Introduction

Teacher knowledge, as is known, is divided into seven types as "content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, and knowledge of educational ends, purposes, and values and their philosophical and historical grounds" (Shulman, 1987, p. 8). "Content knowledge" is the quantity and quality of knowledge in a teacher's mind. Thinking correctly about "content knowledge" necessitates going beyond the knowledge of certain concepts / phenomena. Teachers cannot identify the phenomena accepted for students in only one field. They should also be able to explain the importance of certain propositions in theory and practice (Shulman, 1986). "Pedagogical knowledge" is the knowledge related to the broad principles and strategies about managing and organising classrooms beyond "content knowledge" (Shulman, 1987, p. 8). "Pedagogical knowledge" is the knowledge teachers need to create learning-teaching situations that include declarative and procedural knowledge of certain processes (such as instruction, classroom management, assessment and evaluation) and student heterogeneity (such as learning processes,

learner characteristics) (Voss et al., 2011, pp. 952, 954). "Pedagogical content knowledge" requires summing up and formulating knowledge to make it understandable to others. It also includes understanding what makes it easier or harder to learn certain topics (for example, prejudices of different-aged students from different backgrounds against learning of the most common subjects and courses) (Shulman, 1986). "Pedagogical content knowledge" is expressed as a particular mixture of "pedagogical knowledge" and "content knowledge" (Shulman, 1987, p. 8).

Combining teacher's "content knowledge", "pedagogical knowledge" and "pedagogical content knowledge" with "technological knowledge", Mishra and Koehler (2006) offered "technological content knowledge", "technological pedagogical knowledge", "technological pedagogical content knowledge". "Technological knowledge" is the knowledge of standard technologies (e.g., books, blackboards, chalk, etc.) and more advanced ones (e.g., digital video, the Internet, etc.) and includes installing and removing hardware and software, creating and saving documents. "Technological content knowledge" is the knowledge of the relation between content and technology because teachers need to find out not only the content they will teach but also how the content can be altered through the use of technology. "Technological pedagogical knowledge" is the knowledge of the elements and capacity of the technologies utilized in the learning-teaching environment and how teaching can change with the use of certain technologies. "Technological pedagogical knowledge" is the knowledge of class records, attendance-absenteeism, record-keeping tools and general technology-based ideas (e.g., Web Quest, chat rooms, and discussion boards). "Technological pedagogical content knowledge" is the basis for teaching through technology and entails the understanding that concepts should be presented through technology. It is the knowledge of pedagogical techniques which utilize technology constructively to teach content, what makes learning of concepts easier or harder, and how technology can solve problems of students, and it is the knowledge of existing knowledge and epistemological theories of students and how technology can be utilized to develop new knowledge on existing knowledge or to make existing knowledge stronger (Mishra & Koehler, 2006).

All these dimensions of teacher knowledge have been studied by scholars. Meta-synthesizing of the research studies is important to develop an understanding of research trends. When meta-synthesis studies on science teaching and science teacher education were examined, it was noticed that the knowledge of pre- and in-service science teachers was relatively less studied both nationally and internationally. International literature shows that there are meta-synthesis studies on the role of reflection in the professional development of primary school mathematics and science teachers (Saylor & Johnson, 2014), learning science through diagrams (Tippett, 2016), the integrity of culturally responsive education and inquiry-based science education in pre-university educational institutions (Brown, 2017), science learning and teaching process in out-of-school learning environments (Ayotte-Beaudet et al., 2017), the performance of students in the United States in science tests within the scope of international assessment studies (TIMSS, PISA) (Huss, 2017), abstracts of doctoral dissertations related to STEM education (Banning & Folkestad, 2012), and STEM learning-teaching practices in middle schools, high schools and informal learning environments (Nite et al., 2017). Few meta-synthesis studies have been detected on pre- and in-service science teachers' knowledge. For example, Abidin (2019) conducted a meta-synthesis study on "pedagogical content knowledge" of science teachers related to character education and found that "pedagogical content knowledge" is necessary, yet not adequate to build students' characters, and that "pedagogical content knowledge" can affect students' interests, motivations and achievements as well as their actions. Halai (2012) also examined 20 action research studies conducted by teachers in Pakistan to develop innovative strategies for science teaching with meta-synthesis. As a result of this meta-synthesis research, it was found that action research conducted by teachers contributed to the growth of their "pedagogical knowledge", "content knowledge" and "pedagogical content knowledge".

When the related literature in Turkey is examined, although meta-synthesis studies were found on predict-observe-explain strategy in science education (Balaydın & Altınok, 2018), STEM (Yıldırım, 2016; Herdem & Ünal, 2018; Ormancı, 2020), research conducted at the 4th-grade level (Bağ

& Çalık, 2018), argumentation (Kabataş Memiş, 2017; Boğar, 2019; İnam & Güven, 2019), the relation between the nature of science and argumentation (Kutluca & Aydın, 2017), nature education (Kahyaoğlu, 2016), scales developed in the science and mathematics education field (Gül & Sözbilir, 2015), entrepreneurship (Deveci & Çepni, 2017), the use of interactive whiteboards in science education (Ormancı et al., 2015), and pre-school science education (Ormancı & Çepni, 2019), no meta-synthesis research was encountered on pre- and in-service science teachers' knowledge. This study on the knowledge of pre- and in-service science teachers in Turkey is expected to provide information on the related literature and guide future research by determining the gaps in the literature.

Aim

In this research, qualitative/mixed studies between 2015 and 2019 on pre- and in-service science teachers' knowledge in Turkey were examined. This research addressed the following questions: (1) what level of knowledge do pre- and in-service science teachers in Turkey have? (2) How can the knowledge of pre- and in-service science teachers in Turkey be improved?

Methods

This is a qualitative, meta-synthesis research in which findings of qualitative research or qualitative findings of mixed-methods research are interpreted, evaluated, and their similarities and differences are revealed and synthesized (Polat & Ay, 2016). A meta-synthesis research includes qualitative studies in a particular field and reveals the similarities and differences comparatively with a qualitative understanding (Çalık & Sözbilir, 2014). Bringing qualitative studies together in a related area, i.e. pre- and in-service science teachers' knowledge, this research aims to expose, describe, and explain "the nuances, taken-for-granted assumptions, and textured milieu of varying accounts in ways that bring fresh insights" (Walsh & Downe, 2005, p. 205).

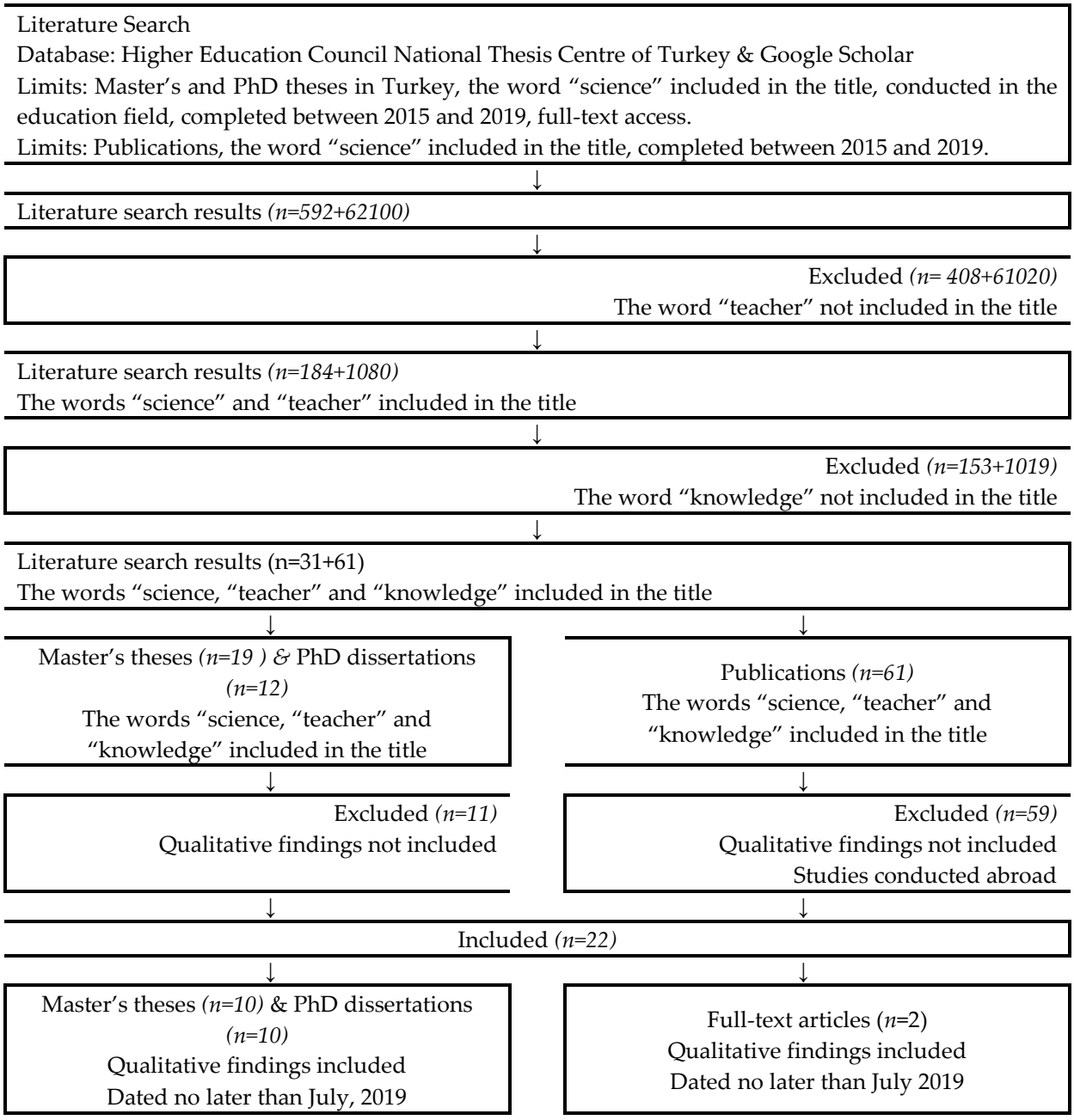
Data Sources

For this meta-synthesis research, where qualitative research method was used, 10 Master's and 10 PhD theses which are available in the archives of Higher Education Council National Thesis Centre and two full-text articles published in the journals indexed in Google Scholar that are related to pre- and in-service science teachers' knowledge provided data. Master's and PhD theses and articles were considered to (a) include the word "science" in the title, (b) be conducted in the education field, (c) be completed between 2015 and 2019, (d) have access permission and (e) include qualitative findings. To access the theses on the knowledge of pre- and in-service science teachers in Turkey in the archive of the Higher Education Council National Thesis Centre, the "Education and Training" title was chosen in the detailed review section and "science" was written in the index section for searching. It was paid attention that these theses were conducted between 2015 and 2019 and they have access permission. 592 theses found were filtered with the word "teacher" and reduced to 184 theses. These 184 theses were filtered with the word "knowledge" and 31 theses including 19 Master's and 12 PhD theses were listed. 11 of the 31 theses listed were excluded from the study since they did not contain qualitative findings, and the remaining 20 theses (10 Master's and 10 PhD theses) were included in the analysis. To access the full-text articles on the knowledge of pre- and in-service science teachers in Turkey published in the journals indexed in Google Scholar, "science" was written in the advanced review section for searching. It was paid attention that the articles were published between 2015 and 2019 and there is access to their full-text versions. 62100 publications found were filtered with the word "teacher" and reduced to 1080 publications. These 1080 publications were filtered with the word "knowledge", and 61 publications were listed. 59 of them were excluded from the study since they did not contain qualitative findings and were conducted abroad, and the remaining two

full-text articles were included in the analysis. A flow diagram of the study selection is presented in Figure 1.

Figure 1

Flow Diagram of the İnclusion of Theses and Articles from the Literature Search Regarding the Knowledge of Pre- And in-Service Science Teachers



The 20 theses and two full-text articles, which were dated no later than July 2019, included in the meta-synthesis were listed in Table 1.

Table 1

Studies Included in the Meta-Synthesis on the Knowledge of Pre- and In-Service Science Teachers

Author	Publication Type	Method	Participants	Knowledge	Theme
Aktaş (2015)	PhD dissertation	Mixed	Pre-service teachers	TPCK	Development
Öktem (2015)	Master's thesis	Qual	Pre-service teachers	PCK	Level
Kılıç (2015)	PhD dissertation	Qual & Quan	Pre-service teachers	TPCK	Development
Eslek (2015)	Master's thesis	Qual & Quan	In-service teachers & middle school students	Other	Level
Akdağ Gürsoy (2015)	PhD dissertation	Mixed	Pre-service teachers	CK	Development
Gencosman (2015)	PhD dissertation	Qual	In-service teachers	TPCK	Level
Gülçiçek (2016)	PhD dissertation	Qual	Pre-service teachers	TPCK	Level
Aydın (2016)	PhD dissertation	Qual	In-service teachers	TPCK	Level
Tatli (2017)	PhD dissertation	Mixed	Pre-service teachers	CK	Development
Akpullukçu (2017)	PhD dissertation	Qual & Quan	In-service teachers	CK	Development
Açıksöz (2017)	Master's thesis	Qual	Pre- and in-service teachers	PCK	Level
Alan (2017)	Master's thesis	Mixed	Pre-service teachers	Other	Development
Gürbüz (2017)	Master's thesis	Mixed	Pre-service teachers	TPCK	Development
Yüce (2017)	Master's thesis	Mixed	Pre-service teachers	CK	Level
Keçeci & Kırbağ Zengin (2017)	Full-text article	Mixed	Pre-service teachers	TPCK	Level
Çet (2018)	Master's thesis	Qual	In-service teachers	CK	Level
Aygen (2018)	Master's thesis	Mixed	Pre-service teachers	Other	Development
Sarı (2018)	Master's thesis	Qual	In-service teachers	TPCK	Level
Ulutaş (2018)	Master's thesis	Mixed	Pre-service teachers	CK	Level
Taşdere (2018)	PhD dissertation	Qual	Pre-service teachers	PCK	Development
Kaya Yatar (2018)	PhD dissertation	Mixed	Pre-service teachers	TPCK	Development
Yılmaz (2018)	Full-text article	Qual	Pre-service teachers	CK	Level

Note. Qual: Qualitative, Quan: Quantitative, CK: "Content knowledge", PCK: "Pedagogical content knowledge", TPCK: "Technological pedagogical content knowledge"

Data Analysis

In the current study where the meta-synthesis stages of Walsh and Downe (2005) are followed, the contents of these theses and full-text articles are analysed and synthesized in depth: (1) Forming research questions, (2) Determining which databases and other resources to look for, (3) Deciding the inclusion and exclusion criteria for the studies found, (4) Selecting which studies to be included, (5) Evaluating the studies and creating tables in methodological and theoretical terms (6) Reading the studies, creating codes and themes, deciding how relevant or irrelevant the research findings are, (7) Synthesizing the research findings and making inferences about this synthesis.

Trustworthiness

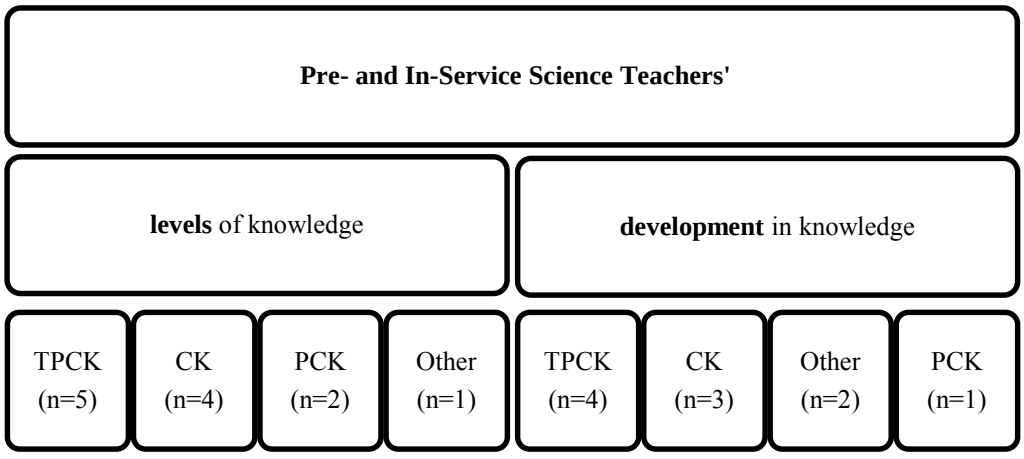
The following strategies were used to ensure the credibility and transferability of the research (Polat & Ay, 2016): The purpose and questions of the research were clearly stated. Data collection method, inclusion and exclusion criteria for the validity of the findings were explained in detail. The number of accessed studies on the subject and the ones included in the meta-synthesis were presented in detail. The method, subject and study group of the included studies were presented in tables. The process of analysing the data and creating common themes was explained in detail and sufficient time was spent for the synthesis of the findings. To guarantee the credibility of the research, the results of some studies examined were quoted.

Findings

It was seen that the Master's and PhD theses and full-text articles on pre- and in-service science teachers' knowledge were related to (a) knowledge levels of pre- and in-service science teachers and (b) development in the knowledge of pre- and in-service science teachers as shown in Figure 2.

Figure 2

Themes Emerging in Meta-Synthesis Regarding The Knowledge of Pre- and In-Service Science Teachers



Note. TPCK: "Technological pedagogical content knowledge"; PCK: "Pedagogical content knowledge", CK: "Content knowledge".

Knowledge Levels of Pre- and In-Service Science Teachers

The theses and full-text articles included in this research strand provided an understanding of the adequacy of pre- and in-service science teachers in terms of their "technological pedagogical

content knowledge" (Gencosman, 2015; Aydın, 2016; Gülçiçek, 2016; Keçeci & Kırbağ Zengin, 2017; Sarı, 2018), "content knowledge" (Yüce, 2017; Çet, 2018; Ulutaş, 2018; Yılmaz, 2018), "pedagogical content knowledge" (Öktem, 2015; Açıksöz, 2017) and "other knowledge" (Eslek, 2015). These studies put emphasis on pre- and in-service science teachers' levels of knowledge related to certain concepts of science such as electricity, electrostatics, electromagnetism, the human body, the structure of and change in matter, pressure, biodiversity and space research. As the qualitative research method dominates the studies as a whole, pre- and in-service science teachers' levels of knowledge have been determined by semi-structured interview protocols, videotaped recordings of lessons, observation forms, and analysis of documents such as science curriculum, (yearly) lesson plans, exams/tests, assessment tools including open-ended questions, worksheets, lesson notes and CDs, concept maps, assignments, presentations and student-made materials. In the studies of Gencosman (2015), Aydın (2016), Açıksöz (2017) and Sarı (2018) carried out to determine in-service science teachers' levels of knowledge, videotaped recordings of lessons were especially used.

"Technological Pedagogical Content Knowledge" Levels (n=5)

In the Master's and PhD theses, in-service science teachers' (Gencosman, 2015; Aydın, 2016; Sarı, 2018) "technological pedagogical content knowledge" levels were investigated. Only one PhD thesis (Gülçiçek, 2016) and the article of Keçeci and Kırbağ Zengin (2017) examined "technological pedagogical content knowledge" levels of pre-service science teachers. "Technological pedagogical content knowledge" levels in relation to "electrostatics" (Gülçiçek, 2016) and "electromagnetism" (Aydın, 2016) were examined especially in PhD theses.

It was emphasized that in-service science teachers volunteered to teach with technology despite some obstacles and performed at different levels as they teach through technology for different purposes and subjects (Gencosman, 2015). It was concluded that science teachers "do not fully integrate content knowledge, technological knowledge and pedagogical knowledge" (Sarı, 2018), but they tend to be more oriented towards teaching science through technology than teachers who graduate from the departments of biology and biology-chemistry teaching and their level of "technological pedagogical content knowledge" is higher and that "content knowledge" is essential to "technological pedagogical content knowledge" (Aydın, 2016). Similarly, Gülçiçek (2016) found that pre-service science teachers develop some misconceptions on electrostatics, restricting them in integrating technology into teaching by combining the content and pedagogical knowledge even if the technological knowledge is sufficient. Correspondingly, Keçeci and Kırbağ Zengin (2017) concluded that pre-service science teachers' level of technological pedagogical content knowledge was moderate and pre-service science teachers felt more competent in technological knowledge, pedagogical knowledge and content knowledge than their teacher educators thought.

"Content Knowledge" Levels (n=4)

Among all theses and articles, pre-service science teachers' (Yüce, 2017; Ulutaş, 2018; Yılmaz, 2018) "content knowledge" levels were mostly investigated. Only one Master's thesis (Çet, 2018) discussed the "content knowledge" levels of in-service science teachers. Especially in the Master's theses and articles, levels of "content knowledge" related to "physics" (Çet, 2018; Yılmaz, 2018) and "biology" (Yüce, 2017) were examined. It was concluded that in-service science teachers lacked the "content knowledge" on the subject of "pressure" (Çet, 2018) since the knowledge gained in universities is mostly theoretical, pre-service science teachers could not relate science and technology knowledge to daily life (Ulutaş, 2018), (as they confuse biodiversity with a variety of species) the courses taken in university were not sufficient (Yüce, 2017). Similar to this finding of the study, one of the findings of one Master's thesis was stated as follows: "Science teacher candidates stated that the information they acquired at the university remained in theory and they did not establish enough relationship with this knowledge in daily life" (Yüce, 2017: 73). A consistent conclusion was also

reached by Yılmaz (2018) who found out that pre-service science teachers' levels of procedural knowledge about and success in the subject of "electricity" were low.

"Pedagogical Content Knowledge" Levels (n=2)

While in one of the two Master's theses, pre-service science teachers' levels of "pedagogical content knowledge" related to "space research" (Öktem, 2015) were investigated, "pedagogical content knowledge" levels of pre- and in-service science teachers were compared in the other (Açıksöz, 2017).

It was found out that pre-service science teachers' "pedagogical content knowledge" (related to space research) was not sufficient (Öktem, 2015), in-service science teachers' "pedagogical content knowledge" was much more than that of pre-service science teachers (Açıksöz, 2017). In contrast to the fact that the lack of "pedagogical content knowledge" of pre-service teachers was pertaining to education, professional development and experience (Öktem, 2015), it was underlined that experience cannot achieve the expected increase in the level of "pedagogical content knowledge" of all teachers (Açıksöz, 2017). This finding was noted by Açıksöz (2017) with the following sentence: «… The result of our study shows that experience is not a criterion for the development of this component ["pedagogical content knowledge"] » (p. 177).

"Other Knowledge" Levels (n=1)

In only one Master's thesis, in-service science teachers' and middle school students' knowledge of project development was examined (Eslek, 2015). It was concluded that in-service science teachers lack adequate knowledge about project development and do not develop projects in accordance with scientific process steps although they state that they do so (Eslek, 2015).

Development of the Knowledge of Pre- and In-Service Science Teachers

The theses in this strand of research identified the development of "technological pedagogical content knowledge" (Aktaş, 2015; Kılıç, 2015; Gürbüz, 2017; Kaya Yatar, 2018), "content knowledge" (Akdağ Gürsoy, 2015; Akpullukçu, 2017; Tatli, 2017), "other knowledge" (Alan, 2017; Aygen, 2018) and "pedagogical content knowledge" (Taşdere, 2018) of pre- and/or in-service science teachers. Mostly, the development of pre-service science teachers' knowledge was studied. The development of pre-service science teachers' knowledge was examined through knowledge-oriented and practice-based teacher education programs (Akdağ Gürsoy, 2015; Aktaş, 2015; Kılıç, 2015; Alan, 2017; Gürbüz, 2017; Kaya Yatar, 2018; Tatli, 2017; Aygen, 2018; Taşdere, 2018). In comparison with the aforementioned studies, there was only one study examining the development of in-service science teachers' "content knowledge" through professional development seminars (Akpullukçu, 2017).

Development of "Technological Pedagogical Content Knowledge" (n=4)

In the Master's and PhD theses, the development of "technological pedagogical content knowledge" of only pre-service science teachers as a consequence of "technological pedagogical content knowledge"-based/oriented teaching process (Aktaş, 2015; Kılıç, 2015; Gürbüz, 2017; Kaya Yatar, 2018) was investigated. It was noteworthy that the development of "technological pedagogical content knowledge" of pre-service science teachers was examined mostly in PhD theses.

It was found out that "technological pedagogical content knowledge" of pre-service science teachers developed as a consequence of informative education, design-microteaching studies and school practice (Aktaş, 2015), "technological pedagogical content knowledge"-based blended learning environment (Kılıç, 2015), "technological pedagogical content knowledge"-oriented education

(Gürbüz, 2017) and technology-supported instruction (Kaya Yatar, 2018). Unlike the studies of Aktaş (2015), Kılıç (2015) and Gürbüz (2017), in only one study, qualitative data revealed that pre-service teachers could not reflect their development in "technological pedagogical content knowledge" into practice (Kaya Yatar, 2018).

Development of "Content Knowledge" (n=3)

In especially the PhD theses, mostly the development in the "content knowledge" of pre-service science teachers (Akdağ Gürsoy, 2015; Tatli, 2017) was investigated. Only one PhD thesis focused on the "content knowledge" development of in-service science teachers (Akpullukçu, 2017). The effect of practice-based courses (Akdağ Gürsoy, 2015) and activities (Tatli, 2017) on the "content knowledge" development of pre-service science teachers and the effect of professional development seminars (Akpullukçu, 2017) on the "content knowledge" development of in-service science teachers were investigated.

It was concluded that the field-specific assessment and evaluation course developed pre-service science teachers' "content knowledge" (Akdağ Gürsoy, 2015). Likewise, watching science-fiction movies and writing science-fiction stories contributed to understanding the scientific knowledge and they can eliminate misconceptions if well planned (Tatli, 2017). It was stated that professional development seminars will contribute to the transformation of science laboratories into safer and more effective areas (Akpullukçu, 2017).

Development of "Other Knowledge" (n=2)

In two Master's theses, the development of pre-service science teachers' integrated teaching knowledge as a result of STEM applications (Alan, 2017; Aygen, 2018) was investigated. In the studies of both Alan (2017) and Aygen (2018), pre-service science teachers stated that STEM education was necessary and important, that the products produced by the integration of different disciplines were much better, but that it was not easy to integrate these disciplines.

Development of "Pedagogical Content Knowledge" (n=1)

In only one PhD thesis, the development of "pedagogical content knowledge" of pre-service science teachers (Taşdere, 2018) was investigated. The growth of pre-service science teachers' "pedagogical content knowledge" on "the nature of science" (Taşdere, 2018) was discussed. Regarding "content knowledge", it was understood that pre-service science teachers developed some misconceptions on "the nature of science". The highest level of development was pertaining to the changeable nature of scientific knowledge, and the lowest level of development was achieved regarding the structure of scientific theory and laws. In terms of knowledge of learners' understandings, it was highlighted that pre-service teachers first presented their misconceptions as possible preliminary knowledge of their students, and then they eliminated the misconceptions to a great extent and stated that the students might have preliminary knowledge related to these misconceptions. A similar development has been achieved in terms of "pedagogical knowledge". Development in terms of knowledge of assessment and evaluation was achieved at a low level because pre-service teachers had difficulty in integrating "content knowledge" into the assessment and evaluation process (Taşdere, 2018).

Discussion, Conclusion and Implications

In the Master's and PhD theses and full-text articles, it was found out that the participants were mostly pre-service science teachers. In most studies, researchers may have wanted to reach a

large number of participants with little time, money and effort. Again, it was understood that the mixed method was mostly used. Since developing instructional systems necessitate the use of different research methods in educational research (Driscoll, 1995 as cited in Göktaş et al., 2012), especially in theses completed between 2015 and 2019, it can be said that the orientations abroad are considered in terms of method (Göktaş et al., 2012).

Among all, it was seen that the studies focused mostly on "technological pedagogical content knowledge" of pre-service science teachers. In parallel with these findings, Baran and Canbazoğlu-Bilici (2015) also found in their research, in which they analysed a total of 30 studies published about "technological pedagogical content knowledge" in the context of Turkey between 2005 and 2013, that "technological pedagogical content knowledge" was mostly studied on pre-service teachers and predominantly in relation to the disciplines of science and mathematics.

It was seen that the studies included in this meta-synthesis were collected in two groups as (a) knowledge levels of pre- and in-service science teachers and (b) development in the knowledge of pre- and in-service science teachers. In a way to support this finding of the research, Gülmez-Dağ and Yıldırım (2016) divided the studies they examined in the meta-synthesis research they conducted on the knowledge of pre- and in-service mathematics teachers in Turkey into two categories as the studies in which the knowledge levels of pre- and in-service mathematics teachers were determined and studies which aim at improving the knowledge of pre- and in-service mathematics teachers.

Regarding the level of "technological pedagogical content knowledge" of pre- and in-service science teachers, it was understood that pre- and in-service science teachers could not fully integrate "content knowledge", "technological knowledge" and "pedagogical knowledge". Pre- and in-service science teachers participating in the studies examined seemed to lack "technological pedagogical content knowledge" with which pre-service science teachers felt competent, though. Karakaya (2012) investigated the relationship between the levels of "technological pedagogical content knowledge" pertaining to global environmental problems (global warming, acid rains, ozone layer) and classroom practices of pre-service science teachers and concluded that "content knowledge" of pre-service science teachers was partially sufficient, "pedagogical content knowledge" and "technological knowledge" were sufficient, "pedagogical knowledge", "technological content knowledge" and "technological pedagogical knowledge" were quite insufficient and "technological pedagogical content knowledge" was insufficient. Ergün (2014) investigated the "technological pedagogical content knowledge" and classroom practices of pre- and in-service science teachers about "refraction of light" and concluded that their "content knowledge" was partially sufficient, "pedagogical content knowledge" was quite insufficient and "technological pedagogical content knowledge" was insufficient. It was concluded that most pre- and in-service science teachers had "technological pedagogical content knowledge - practical" in quite sufficient and sufficient levels, but "technological pedagogical content knowledge - practical" they included in their practice was in insufficient level (Jen et al., 2016). However, Balçın (2016) evaluated pre-service science teachers' "technological pedagogical content knowledge" in the material development process and determined that they reflected "content knowledge", "pedagogical knowledge", "pedagogical content knowledge", "technological content knowledge", "technological pedagogical content knowledge" to the materials they developed in "good" level and "technological knowledge" and "technological pedagogical knowledge" in "very good" level.

Regarding the level of "content knowledge" of pre- and in-service science teachers, it was found out that in-service science teachers' "content knowledge" was not complete and neither was pre-service science teachers'. Pre-service science teachers were not able to relate their science and technology knowledge to daily life, and their courses were not sufficient. It can be inferred that pre-service science teachers especially were not able to transfer what they have learned. It can be thought that this is due to the fact that content knowledge is taught independently from daily life or not taught in a way that allows them to associate with daily life in teacher education programs. Perhaps for these reasons, in-service science teachers may lack "content knowledge". In parallel with the findings related to "content knowledge", Taşcan and Ünal (2016) observed that science teachers could not

answer multiple-choice questions (related to astronomy). Lederman and Chang (1997, p. 119) stated that pre-service science teachers' "content knowledge" was not well-structured; it was disconnected, inconsistent and incompatible (as cited in Kind, 2014).

Concerning the level of "pedagogical content knowledge" of pre- and in-service science teachers, it was found out that pre-service science teachers' "pedagogical content knowledge" was not sufficient, the "pedagogical content knowledge" of in-service science teachers was much more sufficient than that of pre-service science teachers. This can be considered as an expected result because in-service teachers may have developed their knowledge of "how" to teach "what" based on their teaching experience. Pedagogical content knowledge is the knowledge that teachers have developed over time and through experience about how to teach specific content in specific ways to lead students to better understanding (Loughran et al., 2012). As a consequence of 28 studies they examined in relation to science teacher education, Aydın and Boz (2012) determined that pre- and in-service science teachers had some deficiencies related to "pedagogical content knowledge", "pedagogical knowledge" and "content knowledge". Uşak (2009) studied the "pedagogical content knowledge" levels of pre-service science teachers (regarding cell) and concluded that the pre-service science teachers had deficiencies regarding special methods of instruction, they had a more teacher-directed teaching approach, but their self-confidence level related to the "content knowledge" was high.

Regarding the level of "other knowledge" of pre- and in-service science teachers, it was understood that in-service science teachers did not have adequate knowledge about developing projects. In parallel with this finding, it was concluded that in-service science teachers did not perceive themselves as competent during the project development process, could not produce new ideas for the project or could not find a project subject and could not write a project evaluation report (Timur & İmer Çetin, 2017). It seems that the content of science teacher education programs needs to be selected and organized in a way that will enable pre-service science teachers to graduate by developing projects.

As a result of this research on the development of "technological pedagogical content knowledge" of pre- and in-service science teachers, it was found out that "technological pedagogical content knowledge" of pre-service science teachers developed as a consequence of provided informative education, design-microteaching studies and school practice, "technological pedagogical content knowledge"-based blended learning environment, "technological pedagogical content knowledge"-based education, technology-supported teaching. It can be thought that pre-service science teachers' "technological pedagogical content knowledge" can be improved if technology is especially integrated into the content of methods courses in science teacher education programs. Kaleli Yılmaz (2015), as a result of her meta-synthesis research on "technological pedagogical content knowledge", concluded that different teaching practices such as "technological pedagogical content knowledge" workshops, mixed professional development programs and blended learning developed "technological pedagogical content knowledge".

Regarding the development of pre- and in-service science teachers' "content knowledge", it was understood that applied assessment and evaluation course related to the field and watching science fiction films and writing stories improve the "content knowledge" of pre-service science teachers, and professional development seminars improve in-service science teachers' "content knowledge". It can be thought that the courses that enable pre-service teachers to learn actively and in-service training for teachers contribute to the development of "content knowledge". It was underlined that professional training and development systems to teach them the required basics of knowledge ("content knowledge", "pedagogical knowledge" and "subject-specific professional knowledge") are needed to train qualified science teachers (Neumann et al., 2019).

Considering the development of "other knowledge" of pre- and in-service science teachers, it was understood that pre-service science teachers developed scientific process and problem-solving skills throughout the process and STEM applications developed creativity and the skills for the 21st century. It can be said that pre-service teachers have developed 21st-century knowledge. In fact, it was

stated that the main objective of many STEM initiatives was to higher the number and quality of STEM teachers and that well-trained teachers can thus develop their students' 21st-century skills and innovation capacities (Çorlu et al., 2014).

Considering the development of pre- and in-service science teachers' "pedagogical content knowledge", it was determined that regarding "content knowledge" and "pedagogical knowledge", pre-service science teachers achieved the highest level of development pertaining to the changing nature of the scientific knowledge, pre-service teachers eliminated their own misconceptions in terms of knowledge of understandings of learners and expressed that students may have preliminary knowledge related to these misconceptions but they achieved a very low development level in terms of knowledge of assessment and evaluation. It can be asserted that pre-service teachers need to be offered a practical and content-related assessment and evaluation course. Correspondingly, Kartal, Yamak and Kavak (2017) investigated the impact of microteaching on the growth of pre-service science teachers' "pedagogical content knowledge" (on "heat and temperature") and found that pre-service teachers thought that microteaching improved their knowledge about assessment and evaluation, knowledge related to learners' understandings and teacher self-efficacy. It was understood that the "pedagogical content knowledge" of pre-service science teachers developed as a consequence of supportive training (Pirpiroğlu & Doğru, 2015).

"Technological pedagogical content knowledge" deficiencies of pre- and/or in-service science teachers can be eliminated with "technological pedagogical content knowledge"-based teaching practices, "pedagogical content knowledge" deficiencies with considering "pedagogical content knowledge" components in an integrated manner, "content knowledge" deficiencies with professional development seminars. This meta-synthesis research revealed that no studies with qualitative findings examining the development of "technological pedagogical content knowledge" of in-service science teachers are encountered between 2015 and 2019. Hence, future studies which examine qualitatively the growth of in-service science teachers' "technological pedagogical content knowledge", as well as the level and development of pre- and in-service science teachers' other knowledge types ("curriculum knowledge", "knowledge of learners and their characteristics", "knowledge of educational contexts", "knowledge of educational ends, purposes, and values and their philosophical and historical grounds", "technological knowledge", "technological content knowledge", and "technological pedagogical knowledge"), still seem to be needed. For this reason, the following key terms can be recommended to be searched for: "teacher learning", "technological pedagogical content knowledge", "TPACK", and "science" in future meta-syntheses. The recent research on the pedagogical content knowledge studies in science education synthesized (Alkış Küçükaydın, 2019), the levels of pre-service science teachers' content knowledge (Aydın & Hafızoğlu, 2019) and curriculum knowledge (Rahayu & Osman, 2019), the levels of in-service physics teachers' content knowledge (Karaca & Simsek, 2019), the development of pre-service science teachers' pedagogical content knowledge (Smetana et al., 2020), the levels of in-service science teachers' pedagogical content knowledge (Mikeska et al., 2021), content knowledge, curriculum knowledge, and knowledge of educational contexts (Nkanyani & Mudau, 2019), and the recent research on the development of in-service science teachers' technological pedagogical content knowledge (Cheah et al., 2019), which is few in number, confirms the need for such studies as well.

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