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Interaction among Contextual Knowledge and Pedagogical Content Knowledge: Sociocultural Perspective

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Abstract

This study examined middle school science teachers' contextual knowledge, pedagogical content knowledge and impact of contextual knowledge on pedagogical content knowledge based on sociocultural perspective. Data were collected from two teachers through semi-structured contextual knowledge interview, semi-structured pedagogical content knowledge interview, and classroom observations and then data were analyzed by deductive and inductive coding. Findings revealed four assertions regarding how teachers' contextual knowledge impacts their pedagogical content knowledge. Accordingly, a) Teachers' contextual knowledge assists them to make adjustments on their pedagogical content knowledge, b) Teachers' contextual knowledge can support their pedagogical content knowledge in some instances, c) Teachers may not always be able to eliminate negative effects of contextual factors, which limits their pedagogical content knowledge, d) Even though teachers are not aware of contextual factors, these contextual factors still affect their pedagogical content knowledge either positively or negatively. Findings of the study also provide information regarding teachers' contextual knowledge and pedagogical content knowledge in density topic. It is believed that this study provides significant clues about science teachers' contextual knowledge impact on their pedagogical content knowledge, which facilitates teaching and learning of density topic.

Keywords

Pedagogical content knowledge
Contextual knowledge
Density topic
Interaction among contextual knowledge and pedagogical content knowledge

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Introduction

Shulman (1987) claimed that teaching is a complex process and teacher knowledge should be investigated to better understand this process, thus he revealed seven different teacher knowledge types namely; content knowledge, general pedagogical knowledge, curricular knowledge, pedagogical content knowledge (PCK), knowledge of students, contextual knowledge, and knowledge of educational ends, purposes, and values. He defined PCK as knowledge base that teacher use while determining needs of students and selecting appropriate instructional strategies based on these needs and utilizing appropriate assessment techniques in order to assist students' learning (Shulman, 1987).

One of the teacher knowledge types proposed by Shulman (1987) is contextual knowledge. According to Grossman (1990), teacher contextual knowledge includes four components, which are student, school, community, and district (country conditions). Moreover, she advocated that teachers should be aware of these components. Teacher contextual knowledge shows its prominence in recent explanations about PCK. For example; Shulman (2015) summarizes the deficiencies of his past ideas about PCK (Shulman, 1987) as follows: PCK a) focuses on cognitive aspects such as content knowledge by ignoring affective aspects of teaching which are emotions, attitudes, motivation and ethics, b) deals with teachers' knowledge in mind and ignores how teachers transfer their knowledge into practice, and c) does not respond to questions about social and cultural context. Hence, PCK was accepted as a form of knowledge that is independent from environment and its culture. However, Shulman (2015) claimed that teachers should be familiar with the social and cultural environment of where teaching occurs.

Shulman's (2015) recent assertions on PCK pointed that contextual knowledge has significant impact on teachers' PCK. Due to fact that teachers' PCK is closely related with social and cultural environment, this study adopted sociocultural perspective. According to sociocultural approach, people should communicate with other people (e.g., student and teacher) that create interactions in social plane (e.g., classroom) (Anderson, 2007). Similar to Shulman's (2015) new ideas about PCK, importance of contextual factors in teaching was considered in PCK summit held by PCK experts (Gess-Newsome, 2015). Accordingly, there are some contextual factors facilitating and limiting teaching and these factors align with teacher's contextual knowledge. Teachers use their beliefs, goals, orientations, and perspectives to perform their professional knowledge. For example, teacher's interest about selected content may facilitate teaching. Similar to teacher factors, student related factors could facilitate or limit teaching. To this end, student behaviours, reactions to lessons, their resistance to teaching may positively or negatively affect teaching (Gess-Newsome, 2015). To sum up, recent explanations and summit reports about teacher knowledge types suggested that teaching is not isolated from contextual factors and contextual factors should not be ignored in research on teacher professional knowledge.

Theoretical Framework

Various models have been proposed to better understand and analyze teachers' PCK in science education (Cochran, DeRuiter, & King, 1993; Gess-Newsome, 2015; Magnusson, Borko, & Krajcik, 1999; Park & Oliver, 2008; Veal & MaKinster, 1999). Accordingly, Cochran et al. (1993) claimed that PCK is an active process, thus researchers named it as pedagogical content knowing. Cochran et al. (1993) reported that there are four components of PCK which are knowledge of pedagogy, knowledge of subject matter, knowledge of student, and knowledge of educational context. Researchers suggested that these four components are simultaneously integrated to improve pedagogical content knowing. On the other hand, Magnusson et al. (1999) reported their PCK model that is the transformation of other teacher knowledge types (e.g., content knowledge). In this model, PCK includes five different components which are orientation towards science, knowledge of science curriculum, knowledge of students' understandings, knowledge of assessment in science and knowledge of instructional strategies. Magnusson et al. (1999) PCK model is popular in PCK research and recent models (i.e., Gess-Newsome, 2015; Park & Oliver, 2008) were proposed based on the Magnusson model. Park and Oliver constructed their PCK model on Magnusson's model. However, there are some differences between these two models. Firstly, Park and Oliver (2008) added a new component to the PCK which is teacher efficacy. Secondly, researchers considered teachers' planning, actions and reflections as part of PCK. Moreover, researchers emphasized the interactions between PCK components in their model. The last model explaining teachers' professional knowledge is Consensus model (Gess-Newsome, 2015). Consensus model includes not only PCK but also other important parts of teacher professional knowledge (e.g., amplifiers and filters of teaching, student, student achievement etc.). In this professional knowledge, teachers develop their professional knowledge bases (e.g., content knowledge) through their undergraduate program. Next, teachers develop their topic-specific professional knowledge (e.g., science practices) which is idealized knowledge and independent from teaching context. After that, amplifiers and filters (e.g., teacher beliefs, context) show their importance before teaching. Then, teachers perform their personal PCK that is unique to the teacher. In this performance, teacher considers classroom context. These personal PCK components are same with components proposed by the Magnusson model. After enactment of personal PCK, the teacher gets feedback about his/her teaching based on student outcomes (e.g., achievement) and adjusts PCK based on these outcomes.

In this study, we deal with the interaction between contextual knowledge and PCK. To better understand the interaction between two knowledge types; the framework that we use should claim that contextual knowledge and PCK are totally different. Therefore, Cochran's model was not preferred because PCK includes contextual knowledge in this model. Likewise, Consensus model was not preferred since this model was far too broad for PCK and it included both PCK and contextual knowledge components such as student and teacher beliefs. Park and Oliver (2008) PCK model was not preferred too because of the lack of emphasis of this model on teacher knowledge types (e.g. contextual knowledge). On the other hand, Magnusson model explicitly claimed that contextual knowledge and PCK are distinct knowledge types. The distinction between different knowledge types in Magnusson model enabled us to use this model to reveal the interaction among contextual knowledge and PCK.

There are also some other reasons why Magnusson model was used in this study: Accordingly, this model is unique to science education and it deals with important aspects of teaching like assessment and instructional strategies. Moreover, Magnusson et al.'s (1999) PCK model is consistent with the Consensus Model, which was proposed by PCK experts in PCK summit 2015. The model includes five components, which are orientation towards science teaching, knowledge of curriculum, knowledge of learners, knowledge of assessment, and knowledge of instructional strategies. Orientation towards science teaching component deals with the aim of science in particular grade level and represents teacher's general view of science education and shapes other PCK components. Regarding the orientations towards science teaching, orientations that Magnusson et al. (1999) proposed were not used in this study. The reasons are unclear structure of orientations, the lack of relationship between teacher orientation and other PCK components, the lack of evidence pointing out teachers' orientations, unexplained structure of orientations, and orientations' characteristics that neglect the complex structure of teacher beliefs (Friedrichsen, van Driel, & Abell, 2011). On the other hand, beliefs about goals of science teaching proposed by Friedrichsen et al. (2011) were utilized to represent teachers' orientation. In this study, teachers' beliefs about goals of science teaching were categorized in three groups namely schooling, affective, and subject-matter goals (Friedrichsen & Dana, 2005). Teachers adopting schooling goals connect science content into daily life and aim to prepare students in real life while teachers adopting affective goals aim to increase students' interest towards science through science activities and to enhance students' curiosity. Teachers having subject-matter goals emphasize science content and try to increase students' understandings (Friedrichsen & Dana, 2005). Magnusson et al.'s (1999) definitions formed the basis for other four components of the PCK except orientation in this study. Knowledge of curriculum component includes teachers' knowledge about goals, objectives, special programs and resources found in curriculum. Knowledge of learners is based on knowledge of requirements for learning and knowledge of students' difficulty. Knowledge of assessment includes what teacher assesses (e.g., knowledge and attitudes) and how teacher assesses in science. Lastly, knowledge of instructional strategies is comprised of two sub-components, which are subject-specific instructional strategies and topic-specific instructional strategies. Subject-specific instructional strategies are related with general teaching methods and strategies in science whereas topic-specific strategies include activities and representations used in teaching specific science topic (Magnusson et al., 1999). PCK is known its topic specific nature, in other words; there are specific type of assessment, instructional strategies and student misconceptions for each science topic (Magnusson et al., 1999; Veal & MaKinster, 1999). As PCK is topic-specific, we investigated teachers' orientation and PCK in density topic, which is part of particular structure of matter unit taught in 6th grade level (Ministry of National Education [MONE], 2013). There are different reasons to select density topic, which are a) density topic's relations with daily life, b) difficulty of teaching density topics (Smith, Snir, & Grosslight, 1992), c) common density misconceptions held by high school and middle school students (Hardy, Jonen, Müller, & Stern, 2006) and d) interdisciplinary aspect of topic (MONE, 2013; Next Generation Science Standards [NGSS], 2013). Another reason for the selection of density topic is that there is no PCK study conducted in density topic in Turkey.

Other knowledge type that this study focused on is teachers' contextual knowledge. Contextual knowledge components were derived from Grossman's (1990) views about contextual knowledge, and amplifiers and filters of teaching found in Consensus Model (Gess-Newsome, 2015). According to this model, contextual knowledge is comprised of 5 components: Teacher is first component of contextual knowledge because teachers' beliefs, feelings and other characteristics affect teaching (Gess-Newsome, 2015). Second component of contextual knowledge is student. Students' needs, past experiences, family, weaknesses and strengths, and requests shape teaching (Grossman, 1990). Other factor shaping teaching is school and thus teachers should be knowledgeable about school where they work. Therefore, teachers should know school culture, school rules, and other school related factors influencing teaching (Grossman, 1990). Similarly, teachers should be knowledgeable about the community because community may affect teaching (Grossman, 1990). Lastly, teachers should be aware of the country's conditions, opportunities, expectations, and barriers for teaching (Grossman, 1990). Although PCK is topic-specific, there is not sufficient information supporting that contextual knowledge is topic specific in literature. However, teachers form their contextual knowledge that shape teaching after they recognize the conditions of learning environment (Grossman, 1990). Teachers may challenge with these conditions in teaching all science topics. Therefore, we focused on teachers' contextual knowledge dealing with the conditions of their teaching of density topic. By this way, we both identified teachers' contextual knowledge in density topic, PCK about density and interactions between these two knowledge types in density topic.

While investigating teachers' contextual knowledge and its' interaction with PCK, in this study, teacher contextual knowledge is separated from pedagogical content knowledge because teachers transform their content knowledge, pedagogical knowledge and contextual knowledge to construct new knowledge type for teaching, that is PCK (Magnusson et al., 1999). Hence, this study adopted transformative PCK models. Transformative models try to answer the question that "How does a knowledge type (e.g., contextual knowledge) transform into another knowledge type (i.e., PCK)?" (Kind, 2015). Findings of the current study might be used to explain how science teachers use their contextual knowledge when they form and perform their PCK. Teacher knowledge model used in this study is summarized in figure 1. The model includes teachers' contextual knowledge and PCK with their components. Moreover, arrow sign shows that contextual knowledge affects PCK. Likewise, teachers' pedagogical knowledge and content knowledge influence their PCK (Grossman, 1990; Magnusson et al., 1999). However, pedagogical knowledge and content knowledge are excluded from the scope of the study.

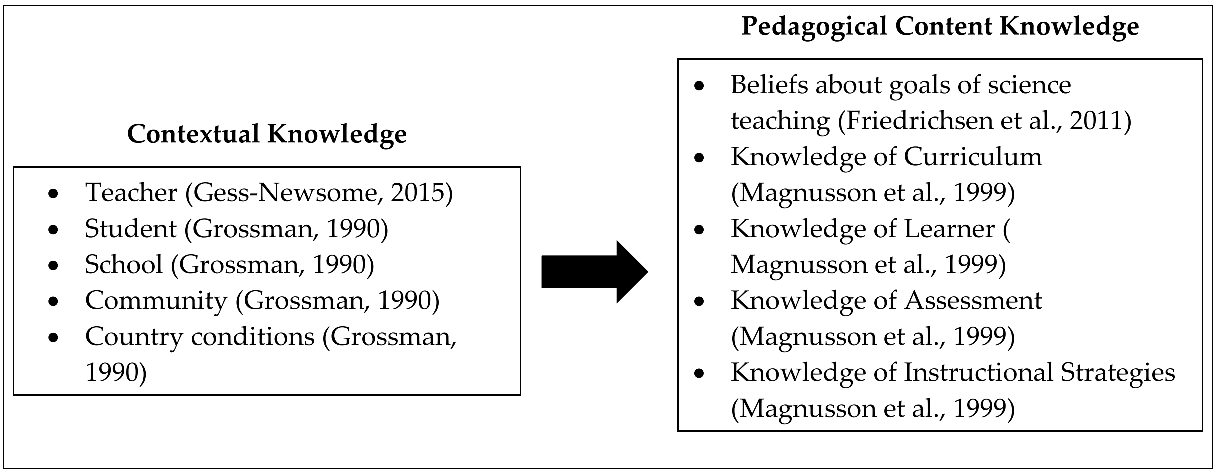

Figure 1. Theoretical Framework

Previous research on PCK has not examined the impact of contextual knowledge on PCK; however, these studies provided important clues about this impact (Arzi & White, 2007; Aydın & Boz, 2012; Aydın, Boz, & Boz, 2010; Avraamidou, 2013; Barnett & Hodson, 2001; Bartos, Lederman, & Lederman, 2014; Cutter–Mackenzie & Smith, 2003; Lee & Luft, 2008; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008; Veal & Kubasko, 2003; Cohen & Yarden, 2009; Zohar & Schwartzer, 2005). For example, previous research showed that pre-service teachers' preparation time for teaching and their concerns about classroom management (Aydın & Boz, 2012), teacher characteristics and background (Aydın et al., 2010) affected pre-service teachers' use of instructional strategies. According to these studies carried out by Aydın et al. (2010), pre-service teachers preferred some instructional strategies in their lessons because pre-service teachers learned science better through these strategies when they were undergraduate students. Likewise, teacher characteristics affected teachers' selection of instructional strategies. For example, pre-service teachers who thought that they were not presentable reported they did not select presentation and discussion methods in their teaching. Similarly, Avraamidou's (2013) study showed that fun science experiments that pre-service teachers attend, field trips that increase pre-service teachers' curiosity and teaching experiences positively affected pre-service teachers' orientations towards science. Previous research held with in-service teachers also showed that experienced teachers and teachers who got feedback from their previous teaching had richer pedagogical content knowledge comparing with their colleagues; teaching experiences and method courses taken in undergraduate level affect the selection of instructional strategy (Bartos et al., 2014); conferences that teachers attend and having a family member working in science related occupation affect teachers' knowledge positively (Arzi & White, 2007) and teachers' reactions to students' questions affect teachers' pedagogical context knowledge (Barnett & Hodson, 2001).

Studies regarding effect of student component on PCK show that teachers change instructional strategy based on students' requests (Aydın et al., 2010). For example, when students said that traditional science lessons were boring; teachers gave up traditional lessons and started to use more enjoyable methods like conducting experiments. Moreover, some other studies suggested that students' questions assisted development of teacher knowledge (Arzi & White, 2007) and students' questions changed the flow of instruction in class (Park & Oliver, 2008).

Regarding the impact of school component on PCK, studies showed that school facilities have significant impact on teacher's PCK (Aydın & Boz, 2012; Aydın et al., 2010; Cutter-Mackenzie & Smith, 2003; Lee & Luft, 2008; Rollnick et al., 2008). For example, Rollnick et al. (2008) reported that teachers having more resources have designed more inquiry based science classes and provided more comprehensive examples. Teachers having fewer resources spent their energy to compensate inadequate resources whereas teachers having more sources spent their energy to improve their content knowledge and PCK. Support of school administration and cooperation between teachers are other school related factors affecting teachers' PCK (Barnett & Hodson, 2001; Bartos et al., 2014). Barnett and

Hodson (2001) reported that cooperation between teachers decreased their concerns and this cooperation improved their knowledge used in class. Literature also showed that school related factors, which are workload (Bartos et al., 2014), school priority for content to be taught (Cutter-Mackenzie & Smith, 2003), school location (Arzi & White, 2007), school policy (Barnett & Hodson, 2001) and school type (Zohar & Schwartzer, 2005) affect teachers' PCK. Considering the impact of school type on teaching, Zohar and Schwartzer (2005) reported that teachers working in religious and authoritarian schools used hypermedia and student centred instruction less than other teachers working in other school types.

Community component usually affects knowledge of learner component of teachers' PCK (Graf, Tekkaya, Kılıç, & Özcan, 2011; Veal & Kubasko, 2003). For example; Graf et al. (2011) in their cross-cultural study stated that sources of pre-service teachers' misconceptions about evolution could stem from pre-service teachers' families and their religious beliefs. Likewise, other studies showed that students' family pressure (Moore & Kraemer, 2005) influences teachers' evolution instruction.

Another contextual knowledge component affecting pedagogical content knowledge is district (conditions of country) (Grossman, 1990; Cohen & Yarden, 2009). Studies show that lesson duration, intense curriculum, teachers' obligations to obey curricular program, and national exams affects PCK. For example, teachers expressed that duration of lessons was inadequate and so they did not prefer to use some instructional strategies even they wanted to use them (Aydın et al., 2010; Cutter-Mackenzie & Smith, 2003). Consistently, intense curriculum could affect teachers' PCK (Cutter-Mackenzie & Smith, 2003). Likewise, obligations to obey curriculum and constraints for teachers' autonomy affect their teaching (Barnett & Hodson, 2001; Bartos et al., 2014; Rollnick et al., 2008). Research also shows that obeying curriculum tightly without any autonomy transforms teachers into technicians who play the role of transmitting curricular content. As a result, teachers could not improve their professional knowledge, which is PCK (Barnett & Hodson, 2001). National exams are another factor affecting teachers' PCK (Cohen & Yarden, 2009; Zohar & Schwartzer, 2005). Accordingly, teachers tend to teach all the objectives asked in national exams in short time. Hence, they prefer to use teacher centred instructions that requires less time (Zohar & Schwartzer, 2005). Likewise, Cohen and Yarden (2009) reported that national exams shape teachers' knowledge of assessment. Accordingly, teachers' knowledge of assessment develops consistent with content and structure of the national exams.

Significance of the Study

First of all, this study is a qualitative study and findings of qualitative studies could not be generalized; however, researchers, science educators, and school administrators could benefit from the findings of the current study if their context is similar to the current research context which was explained in method section. Likewise, teachers and pre-service teachers can benefit from this study if they are similar to the participants of this study which was reported in method section.

It is believed that current study includes some practical and theoretical significance. There is no study examining the interaction between teachers' contextual knowledge and PCK. Findings of the current study might contribute to the theoretical explanation of the interaction between these two knowledge types. Revealing which contextual knowledge impacts which PCK components as a result of this study might provide researchers a baseline to study on these interactions in detail. Similarly, PCK was known as a knowledge type that leads researchers to focus understanding dimension of PCK, and contextual factors were ignored until recently. However, PCK cannot be isolated from contextual factors and teachers' contextual knowledge (Shulman, 2015). Therefore, current study adopted socio-cultural perspective and aimed to investigate the interaction between contextual knowledge and PCK. If other researchers adopt sociocultural perspectives in PCK research and consider teaching as a body of activities implemented as a result of human beings' interactions occur in a social plane, they could obtain much more information regarding the planning, performing and reflections of teachers' PCK. Moreover, factors including teacher beliefs, teaching environment, student beliefs, and student behaviours act as amplifier and filters for teachers PCK according to Consensus Model proposed by PCK experts (Gess-Newsome, 2015). However, Kind (2015) reported that amplifiers and filters' effects on PCK are not well known and there is not enough evidence to support this model. Therefore, findings of this study might contribute on the development of Consensus Model.

Current study also includes practical significance for science teacher educators. Until recently, PCK was thought as knowledge that deals with teachers' cognition (Shulman, 2015) and teacher educators followed the same pathway. For example; they focused on the pedagogical aspects of teaching like instructional strategies (e.g., 5E Learning Cycle) or content knowledge. However, teaching is more than what happens in teachers mind. In other words, PCK not only includes cognition, but it also deals with context that teachers work. In a similar vein, science educators could use socio-cultural factors and teachers' contextual knowledge in their program through PCK research adopting socio-cultural perspectives. Therefore, science educators might emphasize a teacher profile that has an interaction with all members of the community. Therefore, interactions among PCK components and contextual knowledge components revealed in this study could be used by science educators for preparing courses and professional development programs that emphasize how context and contextual knowledge influence teaching. Likewise, data obtained from current research can be used for courses that focus on filters and amplifiers of teaching. Furthermore, participants' weaknesses and strengths about assessment and instructional strategies revealed in this study could be used by science educators to prepare science courses and professional development programs if their pre-service and in-service teachers and context are similar to this study.

This study provides information about science teachers' contextual knowledge, thus science teachers benefit from this study too. Revealing science teachers' contextual knowledge can inform other science teachers regarding contextual knowledge and they consider contextual factors while they plan their teaching. These teachers can adjust their teaching based on their contextual knowledge. Likewise, teachers can learn the situations where contextual factors negatively affect teaching from this study and they have chance to take precautions in their own teaching by eliminating the negative effects of contextual factors. Similarly, other teachers can use contextual factors that act as amplifiers of teaching, which support PCK in current study. By this way, teachers enrich their PCK, increase quality of their teaching, and students can reach more objectives. Similar to in-service teachers, pre-service teachers can benefit from findings. Pre-service teachers are short of experience and they are not familiar with contextual factors; hence, they can develop their contextual knowledge using the results even though they have not enough teaching experience.

Lastly, findings of this study provide feedbacks about science teaching in Turkish public schools. Filters of teaching revealed in this study could be eliminated in other school environments by policy makers. By this way quality of science teaching might increase.

In the light of above mentioned statements, current study has three research questions namely:

1. What is science teachers' contextual knowledge in density topic?

2. What is science teachers' pedagogical content knowledge in density topic?

3. How do science teachers' contextual knowledge and pedagogical content knowledge interact?

Method

This study is an example of basic qualitative research (Merriam & Tisdell, 2016) that is most common type of qualitative study. General aim of this basic qualitative study is to interpret participants' contextual knowledge, pedagogical content knowledge and their interactions in density topic by using interviews and observations. Accordingly, participant teachers constructed their interpretations about their contextual knowledge and PCK. After that as researchers, we constructed our interpretations about science teachers' contextual knowledge, PCK and these two knowledge interactions in this basic qualitative research.

Participants

Two science teachers working in the same public school have participated in the current study. Anonymously, one teacher was named as Ayşe and other teacher was named as Ferhat. Ayşe was a graduate of faculty of arts and sciences and she had 20 years of teaching experience. Ferhat graduated from science education department in faculty of education and he had one-year teaching experience. Both teachers completed four years undergraduate programs. As Ferhat graduated from faculty of education, he took content knowledge related courses and pedagogy courses (e.g., classroom management). On the other hand, Ayşe took just content related courses in her undergraduate years because faculty of arts and sciences did not offer pedagogy courses. After her graduation, she took pedagogy courses and became a science teacher through completing a pedagogical certification program. Both teachers teach science in 5th and 6th grade levels and they do not teach in other grade levels. Moreover, none of the participants attained professional development programs to develop their pedagogical content knowledge.

Purposive sampling was used in this basic qualitative study. According to Creswell (2007), there can be more than one type of purposive sampling in a research setting. Therefore, this study is consistent with three types of purposive sampling. Firstly, this study includes typical sampling (Creswell, 2007) because participants of the study represent typical or average science teachers working in public schools. Secondly, this study includes criterion sampling (Creswell, 2007) because participants were selected based on some criteria determined before the beginning of the study. Accordingly, only teachers working in public schools were invited to take part in the study and teachers working in private schools were not selected. Likewise, only science teachers teaching in 6th grade level where density topic is taught were included. Therefore, other science teachers teaching in other grade levels were excluded. Thirdly, this study is consistent with convenient sampling (Creswell, 2007) because we selected one school, which facilitate the applicability of the study and other schools were not preferred because of the potential difficulties (e.g., transportation) for conducting the research. The reason why we studied with two teachers from the same school was not to compare teachers' contextual knowledge and attribute the potential differences of their contextual knowledge to their differing PCK. The reason why two teachers were selected from the same school was to get more information regarding contextual knowledge, PCK and their interaction by increasing number of participant. Therefore, data obtained from two teachers enrich the results related with these two knowledge types and their possible interactions.

This study was conducted in one of the central district of Ankara province. The socioeconomic level of people living in the area was medium. The school has a science laboratory, but teachers do not use it in general. Teachers conduct science lessons in classroom. Seating arrangement was in traditional row. This classroom design reminds of traditional teaching in which teacher transmits the knowledge and students are the passive receivers of the subject matter. Observations confirmed that teachers followed traditional teaching. Approximately, there were 20 to 25 students in each class. School followed the curriculum suggested by MONE (2013) as other public schools do. According to Turkish science curriculum (MONE, 2013), students are expected to learn content knowledge (e.g., physics), develop science related skills (e.g., science process skills), gain values in science related affective domains (e.g., attitudes towards science) and increase awareness about science-technology-society and environment issues (e.g., socio-scientific issues). Curricular program mainly suggests teachers to use inquiry-based approaches in their teaching (e.g., argumentation). Role of student is described as the one who seek knowledge, conduct inquiry, discuss and construct knowledge (MONE, 2013). On the other hand, teacher is described as the one who is the guide and facilitator for students during learning (MONE, 2013). The methods and instructional strategies that teachers are expected to use in science teaching are student centred such as problem based learning, project based learning, argumentation, and cooperative learning (MONE, 2013).

This study's specific topic "Density" is taught in third unit (particular structure of matter unit) at 6th grade level (MONE, 2013). At the end of density topic, curriculum expects students to define density, know the unit of density, conduct experiment about density, compare the results of the density experiments, conduct inquiry about the importance of densities of different phases of water for living organisms (MONE, 2013). Prerequisite knowledge for students to learn density topic are structure of matter taught in 6th grade level, changes of the states of matter taught in 5th grade level, measurable properties of matter (i.e., mass and volume) and states of matter taught in 4th grade level. Other density related topics placed in middle school science curriculum are structure of matter and separation of mixtures taught in 7th grade level (MONE, 2013).

Data Collection Tools

This study aims to answer three research questions and these questions are related with teachers' contextual knowledge, PCK, and interaction between contextual knowledge and PCK. To obtain data regarding participants' contextual knowledge, we prepared contextual knowledge semi-structured interviews and conducted interviews with two participants. Contextual knowledge interview questions were prepared based on the five components (e.g., school component) reported in theoretical framework. Semi-structured contextual knowledge interviews included seven questions. One question was related with contextual knowledge in general without considering any specific contextual knowledge component. Two of the questions were related with teacher component of context, one question was about student component, one question asked information about school component, one question was about community component and other two questions asked information about country conditions. Contextual knowledge interviews lasted nearly half an hour for each participant and interviews were sound recorded. Then data were transcribed and prepared for data analysis process. Two contextual knowledge interview questions are given below as example:

<u>Question:</u> Are there any factors that amplify or filter your density teaching in general?
If yes, what are these factors? Can you give examples?
If no, can you justify your answer?

<u>Question:</u> Do you think that your students affect your teaching when you teach density? *(Student component)*
If you think they affect your teaching, can you provide any example showing how students affect your teaching?
If you think students do not affect your teaching, can you justify your answer?

Second research question of the study aimed to investigate science teachers' pedagogical content knowledge in density topic. Based on the theoretical framework and PCK literature, we prepared semi-structured PCK interview protocol. After preparing PCK interviews, we got feedbacks for questions from the PCK experts to increase trustworthiness of the study. According to this, PCK interviews included 17 questions in total. Two of them were about beliefs about goals of science teaching, five of the questions were about knowledge of curriculum, four of them were about knowledge of learner, three of them were about knowledge of assessment and three of the questions were related with knowledge of instructional strategies. PCK interviews lasted nearly one hour for each participant and interviews were recorded. After that data were transcribed and prepared for data analysis. Two of the PCK interview questions were provided below as examples.

Question: Do you use representations (visuals, figures, simulations, drawings and analogies) in your density teaching to support students' learning? *(Knowledge of Instructional Strategies)*
If you use, what are these representations? Can you give topic-specific examples?
If you do not use representations, what is your reasoning?

Question: Do you think that density topic is related with other topics, units, and the same or other grade levels? *(Knowledge of curriculum)*
If you think it is related, what are these topics? Can you explain your answer?
If you think density is not related with other topics, can you explain your answer?

PCK interviews provide data just for teachers' planned PCK in their mind, and it does not give information about their enactment of PCK in class. Therefore, we aimed to obtain evidence from their enacted PCK as evident in classes and therefore we prepared PCK observation form based on theoretical framework and relevant PCK literature (see appendix 1). The first researcher filled up observation forms for each lesson. PCK observation forms represented each teacher's enactment of PCK in class about density topic and five components of the PCK reported in theoretical framework. During observation, researcher sat at the backmost of the desks to fill in observation form. Researcher did not interrupt events happening in class and just he observed them, therefore role of the researcher was non-participant observer during observations (Merriam, 2009). Observations lasted eight hours for each teacher and 16 hours in total.

Third research question focused on investigating the interaction between contextual knowledge and PCK. There was no specific data collection tool to answer this research question. On the other hand, we re-examined data obtained from contextual knowledge interviews, PCK interviews and PCK observation forms to understand the potential interactions among teachers' contextual knowledge and PCK. For example, a teacher might explain her views about school effect on her teaching during contextual knowledge interviews conducted for answering first research question (i.e., contextual knowledge). Re-examination of this explanation for the third research question (i.e., interaction between contextual knowledge and PCK) might reveal evidence that there is an interaction between school component of contextual knowledge and knowledge of instructional strategies component of PCK. Likewise, a teacher might explain her knowledge of curriculum for second research question (i.e., PCK) and s/he might mention country conditions in her reasoning. Re-examination of these statements based on third research question might reveal that there is an interaction between country conditions component of contextual knowledge and knowledge of curriculum component of PCK.

Data Analysis

The data were analysed to gain an in-depth understanding about the three research questions in this study. Teachers' contextual knowledge was revealed through analysis of contextual knowledge interviews. Both deductive coding and inductive coding were used in contextual knowledge analysis. Deductive coding was used for the analysis since categories for contextual knowledge already exist in theoretical framework and utilized as they are. During interviews, there were some codes, which were not found in literature, and these codes were added to contextual knowledge analysis by use of inductive coding. Table 1 provides examples of codes and categories regarding contextual knowledge analysis.

Table 1. Code and Category Examples about Contextual Knowledge

Category	Category Source	Deductive Code	Source of Deductive Code	Inductive Code
Teacher	Gess-Newsome (2015)	Preparation time for teaching	Aydın and Boz (2012)	Teacher Interest
Student	Grossman (1990)	Student questions	Park and Oliver (2008)	Student Interest
School	Grossman (1990)	School resources	Rollnick et al. (2008)	-
Community	Grossman (1990)	Students' families	Graf et al. (2011)	-
Country Conditions	Grossman (1990)	Intensity of curriculum	Cutter-Mackenzie and Smith (2003)	-

Second research question was about revealing science teachers' PCK in density. Data obtained from PCK interviews and PCK observation forms were deductively analyzed to reveal science teachers' PCK. In deductive coding of PCK analysis, we used our theoretical framework for PCK, which are the studies of Magnusson et al. (1999) and Friedrichsen et al. (2011). Therefore, we used five categories (e.g., knowledge of curriculum) for PCK analysis consistent with theoretical framework. Moreover, some additional codes from PCK literature (e.g., curricular violation code as part of knowledge of curriculum used in Kind, 2009) were used under these categories in PCK analysis process even though these codes were not used in Magnusson et al. (1999) and Friedrichsen et al. (2011) studies. Examples of codes and categories regarding PCK analysis are provided in table 2:

Table 2. Code and Category Examples about Pedagogical Content Knowledge

Category	Category Source	Deductive Code	Source of Deductive Code
Orientation towards science teaching	Friedrichsen et al. (2011)	Schooling goals	Friedrichsen and Dana (2005)
Knowledge of Curriculum	Magnusson et al. (1999)	Curricular violations	Kind (2009)
Knowledge of Learner	Magnusson et al. (1999)	Misconceptions	Magnusson et al. (1999)
Knowledge of Assessment	Magnusson et al. (1999)	Level of question	Hashweh (1987)
Knowledge of Instructional Strategies	Magnusson et al. (1999)	Topic specific strategies	Magnusson et al. (1999)

After analysis of teachers' contextual knowledge and PCK, data obtained from all interviews and observations were re-used to reveal interaction between contextual knowledge and PCK. This analysis provided findings about interaction between these two knowledge types and was used for third research question. There was no available code or category regarding the interaction between PCK and contextual knowledge in literature. Therefore, we inductively analyzed the interaction between these knowledge types. Sample coding for interaction between contextual knowledge and PCK is provided in table 3. First analysis example was taken from contextual knowledge interviews of Ferhat. In this example, Ferhat claimed that his past experiences (teacher component of contextual knowledge) affect his knowledge of learner:

> "I had difficulty in learning density topic when I was student. This experience guided me teach density topic to students…Because I could not divide mass to the volume thus had difficulty in calculating density. Students will have similar problems that I had

experienced…Because we have common problems in learning density topic. My knowledge about their difficulty and my adjustment of teaching based on these difficulties will facilitate their learning." (Ferhat, contextual knowledge Interview)

Depending on this explanation, it is understood that Ferhat established an interaction between his past experiences as part of teacher component of contextual knowledge and students' difficulties as part of knowledge of learner component of PCK. As a result of this interaction, it can be asserted that contextual knowledge might feed teachers' PCK.

Second analysis example regarding contextual knowledge and PCK interaction given in table 3 were obtained from observation of Ayşe's classroom instruction. Accordingly, Ayşe reported that she did not conduct density experiment because there is no equal arm scale in school. Instead of this experiment, Ayşe drew figures representing this experiment in class. This situation shows that teacher established an interaction between lack of materials code of school component of contextual knowledge and topic specific activities part of knowledge of instructional strategies component of PCK. According to this interaction, teacher changed the instructional strategy because there is no related material. In other words, teacher made an adjustment in her teaching considering the context. Based on this interaction, it can be asserted that: "When contextual factors affect teaching negatively, teachers divert to other strategies from their teaching repertoire."

Table 3. Example of Data Analysis Regarding the Interaction between Contextual Knowledge and PCK

Evidence for Contextual Knowledge	Evidence for PCK	Interaction between PCK and Contextual Knowledge	Assertion
Teacher-Teacher Experience	Knowledge of learner-knowing students' difficulties about density	Teacher component of contextual knowledge interacted with knowledge of learner component of PCK	Teacher contextual knowledge can support their PCK.
School-Lack of School materials	Knowledge of Instructional Strategies-Teacher did not conduct experiment, instead she used representations	School component of contextual knowledge interacted with knowledge of instructional strategies component of PCK	When contextual factors affect teaching negatively, teachers divert to other strategies from their teaching repertoire.

Trustworthiness of the Study

Different methods were used in order to increase trustworthiness of the study. First of all, we used data triangulation (Patton, 1990). Therefore, we compared data coming from interviews and observations to check data and to better understand participants' knowledge. Likewise, different examples of same data sources were compared with each other. For example, we analyzed each observation form separately for the same teacher, and then we compared the results of different observation forms to reveal this teacher's application of PCK. Next, we used investigator triangulation to increase trustworthiness. According to this, researchers coded contextual knowledge interviews separately and inter-rater agreement was found as 85%. Likewise, PCK interviews were found as 90% and interaction between PCK and contextual knowledge inter rater agreement was found as 95%. We discussed about conflicts and after discussions we reached consensus about codes, categories and assertions. Inter-rater agreement was found based on the formula proposed by Miles and Huberman (1994) that is.

$$\frac{\text{Number of agreement}}{\text{Number of agreement + disagreement}}$$

Moreover, we shared our data with participants and asked them whether they want to add or reject something. Participants confirmed the data and member check increased trustworthiness of the study (Merriam, 2009). Researchers' prior experiences about study are another important thing that increases trustworthiness of the study (Patton, 2005). As researchers of this study, we are familiar with PCK research because we have previous work (e.g., thesis, article etc.) on this topic. Likewise, we consulted one PCK expert before, during and after the study and this expert shared her ideas and provided us some feedbacks about the study. By this way, study was evaluated by an objective person that increased trustworthiness of the study more (Merriam, 2009).

Regarding transferability, findings of this study cannot be generalized to other schools because this is a qualitative study; however, other typical science teachers working in similar environment (i.e., public school) can benefit from results. So, findings can be transferred to similar contexts (Merriam, 2009). Moreover, this study was conducted with two science teachers. One of the teachers was not experienced and other teacher was experienced. Experienced teachers' results can be transferred to other experienced teachers and novice teachers' results can be transferred to other novice teachers. Therefore, variation of participants' experience can be advantage for transferring results to other conditions. By this way, both novice and experienced teachers can benefit from the findings.

Procedure

We communicated with Ministry of National Education to get permission and to conduct the study for ethical concerns. After the permission of National Education, we contacted with provincial directorate of national education. Then, we met with school principal and science teachers and we briefly described the study without giving detailed information. Then, two of the teachers who met criteria for the study were willing to be participant and we conducted the study with these teachers. Pseudonyms were given to teachers. Data obtained from teachers were not shared with any other people apart from researchers and participants. Moreover, the study did not harm any people or institution.

Results

This study mainly attempted to answer three research questions. In this part, teachers' contextual knowledge, pedagogical content knowledge and interactions between these two knowledge types are reported.

Teachers' Contextual Knowledge

Teachers' contextual knowledge is summarized in Table 4.

Table 4. Teachers' Contextual Knowledge

Teacher	Contextual Knowledge	Teacher Component	Student Component	School Component	Community Component	District Component
Ayşe	*General*	-	-	-	-	Dense curriculum
	Specific to Density	-	Readiness level	Lack of material	-	-
Ferhat	*General*	Teacher interest	Student interest	-	Students' family	Dense curriculum
		Teacher knowledge	Readiness level			
	Specific to Density	Teacher Experiences				
		Teacher views about topic	-	Lack of material	-	-

Teacher Component

When it is asked whether teachers' life, personal characteristics and experiences affect their teaching about density, Ayşe explained that teachers' personal characteristics do not affect their teaching about density; however, Ferhat believed that teachers' interest toward topic and content knowledge facilitate his teaching in general.

> Researcher (R): "What about your personal characteristics and experiences? Do they influence your teaching about density? Can you justify your answer?"
>
> Ayşe: "No, it does not, density is a topic related with physics… We only give daily life examples to children (Interview).
>
> Ferhat: "Of course, your interest affects your teaching. It depends on the extent to which you want to teach. If you voluntarily teach the content, the feedbacks that students provide will be different. Thus, I think personal characteristics are important factor… Knowing the concepts like force, mass and speed made it easier for me to teach density. I was able to give better examples and ask more questions." (Interview)

According to Ayşe, teacher component of contextual knowledge and density teaching are independent from each other. However, Ferhat advocated that teacher and density teaching are not separable. He explained that teacher's personal characteristics affect teacher's general science teaching and density teaching. His explanations also showed that teacher's views about density affect their density teaching. For example, Ferhat supported density teaching because he saw this topic as one of the basic topic:

> "Density is main topic in science. Students will cope with density not only in middle school level, but also other levels of their education…d=m/v is a formula that is seen everywhere. If students learn density topic well in middle school, they can use this knowledge in explaining many events that occur in other science topics." (Interview)

Ferhat not only believed that teachers' characteristics affect their teaching, but he also stated that teacher experiences influence their density teaching. He was knowledgeable about the difficult points of density topic thanks to his personal experiences he gained when he was a student. He added this knowledge gained from his studentship facilitated density teaching:

> "I had difficulty in learning density topic when I was student. This experience guided me teach density topic to students…Because I could not divide mass to the volume thus had difficulty in calculating density. Students will have similar problems that I had experienced…Because we have common problems in learning density topic. My knowledge about their difficulty and my adjustment of teaching based on these difficulties will facilitate their learning." (Interview)

To be brief, while Ayşe believed that teacher characteristics do not affect density teaching, Ferhat supported the view that teacher characteristics (e.g., teacher interest to topic, teacher views about topic) are important for both general science teaching and density teaching. Ferhat also added that his experiences that he gained when he was student developed his knowledge of learner component of PCK that facilitated his density teaching.

Student Component

As indicated in sociocultural theory, teaching occurs in social plane and teacher's instruction is influenced by students with whom teachers interact For example, Ayşe stated that students' readiness level affects her teaching practice in density topic and Ferhat thought that students' characteristics generally impact his science teaching.

> R: "Do you think that students affect your density teaching?"
>
> Ayşe: "Of course [students'] readiness level affects [density teaching]. If students cannot compute mathematical operations, they cannot calculate density. This means that it is difficult for me to get students involved in problem solving activity. Students' ability to compute mathematical operations is indication of their readiness." (Interview)
>
> Ferhat: "Of course [students] affect [teaching] because some students are interested in the topic. Thus, I feel that as if I teach to some students who are interested in… Students' readiness level is the most influential aspect… Students are not ready to learn topic when they start middle school because of their low readiness level. Therefore, we start teaching from easier topic instead of teaching main topic." (Interview)

Findings suggested that both teachers reported students' readiness level as student component of contextual knowledge, which affects their teaching. While Ayşe's example about readiness level was directly related with density topic (i.e., ability to compute mathematical operation), Ferhat's explanation about students' readiness level was more general. Moreover, Ferhat stated that students' interest generally has an effect on his teaching.

School Component

It is revealed that school, another component forming social plane, has influence on teaching. Both teachers reported that lack of teaching material affects their teaching negatively. Ayşe reported that she engaged her students with problem solving activity without conducting experiment because of lack of teaching material. She added that she did not show some visuals because projector device is broken. Likewise, she reported that she did not actively use internet. Similar to Ayşe, Ferhat emphasized the absence of materials. He stated that lack of laboratory materials measuring mass and volume obstructed his density teaching.

R: "Do you think that the school that you worked influences your density teaching?"

Ayşe: "We could not conduct experiment and measure mass because of lack of equal-arm scale. It is not possible to calculate density without measuring mass. Therefore, lack of laboratory materials creates obstacle for conducting experiment in density topic. If we possess laboratory materials, I conduct experiment in this topic [density]. Currently, we just provide values for mass and volume to students and they calculate the density of objects… We have internet in school, but we do not use internet regularly. There is a projector in laboratory, but it is out of order. Accordingly, we cannot show some visuals." (Interview)

Ferhat: "We can conduct density experiment if we have metal and plastic objects having different density, laboratory materials like wide bowl to fill water in it, and beakers to compare density of oil and water. Otherwise, we could not conduct density experiment… Likewise, projector does not work, and we do not show visuals by using projector." (Interview)

In conclusion, both teachers reported lack of materials (i.e., laboratory materials, projector) as barrier to their density teaching.

Community Component

Analysis of the community component showed that teachers have opposing ideas about the impact of community on their teaching. While Ayşe claimed that people living in community do not affect density teaching, Ferhat stated that community affects their teaching in general though it does not directly affect teaching of density topic. For example, Ferhat reported students' family affects his teaching in particular.

R: "Do you think that people living in the community affect your teaching of density?"

Ferhat: "Child is affected from family at home. Well educated parents influence my teaching positively … For example; uneducated families do not read book at home and not spend much time with the children, so children come to school without learning from their family… It is quite difficult to teach these children." (Interview)

Conditions of Country Component

Lastly, the impact of conditions of country component on teachers' density teaching has been investigated regarding contextual knowledge. Both teachers agreed that conditions of the country generally affect their teaching including dense curriculum. Teachers expressed that 6th grade science curriculum in which density is taught was highly dense. They have difficulty in allocating enough time for teaching topics in this grade level, and accordingly they teach the topics too fast.

R: "Do you think that conditions of the district or country affect your density teaching?"

Ayşe: "Curriculum is highly dense especially in 6th grade, so we experienced some problems in teaching curricular content. We have to teach all content too fast without conducting activities offered in the textbook." (Interview)

Ferhat: "When we consider the curriculum in 6th grade level, it is quite dense compared to other levels. 6th grade contains too many topics to be taught. Yet, we have no time." (Interview)

To summarize regarding contextual knowledge, Ayşe stated that conditions of district or country (i.e., dense curriculum), student component (i.e., students' readiness level) and school component (i.e., lack of materials) affected her teaching of density. Ferhat reported that teacher component (i.e., teacher's interest towards topic, teacher's content knowledge), student component (i.e., student interest toward topic, students' readiness level), community component (i.e., students' family), and district component (i.e., intense curriculum) generally affected his teaching. He also mentioned that teacher component (e.g., teacher experiences) and school component (i.e., lack of materials) had impact on density teaching (see table 4).

Teachers' Pedagogical Content Knowledge

Here, teachers' pedagogical content knowledge is presented with respect to five components:

Orientations towards Science Teaching: Teachers' orientations towards science teaching were interpreted based on three different goals proposed by Friedrichsen and Dana (2005), namely schooling goals, subject matter goals and affective goals (see Table 5).

Table 5. Teachers' Orientations towards Science Teaching

		Schooling Goals	**Affective Goals**	**Subject-Matter Goals**
Ayşe	Interview	Make life easier Relation with daily life	-	Increase students' content knowledge
	Observation	-	-	Teaching content knowledge
Ferhat	Interview	Related with daily life	Increase students' curiosity Increase students' interest and attitude towards science Being happy by sharing knowledge	Obligation to obey curriculum Curricular relations among topics
	Observation	-	Increase students' curiosity Increase students' interest towards science	Teaching content knowledge

Interview results showed that Ayşe had schooling and subject-matter goals. Regarding schooling goals, Ayşe stated that science not only makes life easier but also it is directly related with daily life. Moreover, Ayşe's ideas about content knowledge show that she had subject-matter goals.

"I think that aim of the science is to make life easier. Students who know the density topic can differentiate substances having different densities. Density topic is important because it is related with students' daily life. For example, we compare the mass of 1 kg iron and 1kg cotton. I think such kind of knowledge make their life easier… I also teach

> science to make students knowledgeable in physics, chemistry and biology disciplines." (Interview)

Although Ayşe mentioned schooling and subject-matter goals in interviews, she focused on only subject-matter goals during teaching practice. Her subject-matter goals included objectives related

with the "definition of mass, volume, density", "formula of density", "relationship between mass, volume and density", "calculation of density", "comparison of densities of immiscible liquids".

Ferhat's interview results, however, showed that he had schooling, subject-matter and affective goals. Regarding affective goals, Ferhat aimed to increase students' interest and attitude toward science, increase students' curiosity. Moreover, he personally felt happy when he taught science and share his knowledge with students. Ferhat's connection between daily life and science shows that he had schooling goals. Regarding subject-matter goals, he reported that he focused on content knowledge because of curricular obligations and he thought that density topic is pre-requisite for other science topics. This is another situation explaining why he focused on content knowledge.

> "The aim of science teaching could be increasing students' curiosity, interest and attitude towards science. Teaching science make me happy… Science is related with daily life. Students use density when students differentiate substances… However, there is a curriculum we have to obey… Density is not an isolated topic; it is related with other topics. For example; density difference can be used as a method in separation of substances in chemistry." (Interview)

During observations, Ferhat's "floating huge ship and sinking small iron" example took students' attention throughout the lesson and increased students' curiosity. This situation was considered as an indication of his affective goals during his teaching. In addition, Ferhat clearly mentioned his subject-matter goals because he emphasized content knowledge such as "the relationship between mass, volume and density; position of substances having different density in water; calculation of mass, volume and density." To sum up, although there were evidences that Ferhat had affective and subject matter goals, there was no trace of his schooling goals in his teaching.

Knowledge of Curriculum: Teacher's knowledge of curriculum was summarized in table 6:

Table 6. Teacher's Knowledge of Curriculum

Teacher	Objectives	Vertical Relations	Horizontal Relations	Knowledge beyond the curriculum	Resources
Ayşe	Define density and state unit of density Calculate density of matters Compare density of immiscible liquids	Buoyancy States of matter Properties of matter Mixtures Decimal representation of rational numbers Ranking of rational numbers	Speed Particulate nature of matter Ratio Relation between division and rational numbers		Textbook Student workbook

Table 6. Continued

Teacher	Objectives	Vertical Relations	Horizontal Relations	Knowledge beyond the curriculum	Resources
Ferhat	Define density and state unit of density Calculate density of matters Compare density of immiscible liquids	Buoyancy Properties of matter Mixtures Line Graph Rate and proportion	Speed Particulate nature of matter Ratio Calculation of geometrical objects' volume	Change of density Line Graph	Textbook Workbook

Firstly, curricular objectives related with density were asked to the teachers:

R: "Which curricular objectives do you focus on when you teach density?"

Ayşe: "Students comprehend that different substances have different density after they learn density. Students compare the density of different substances in their surroundings… Students calculate and compare density of objects based on particular mass and volume." (Interview)

During observations, Ayşe focused on definition and formula of density. When students calculate density, they did not conduct experiment. Likewise, when she taught the comparison of immiscible liquids' density, students did not conduct experiment. Instead of experiment, Ayşe showed visuals about the position of immiscible liquids (water and oil) in beaker.

Ferhat's knowledge about curricular objectives was consistent with Ayşe's knowledge. According to Ferhat, density objectives were related with definition of density, calculation of substances density, and comparison of different substances' density:

Ferhat: "At the end of the lesson, students define density; calculate density by comparing mass and volume. [Students] compare different substances' density by doing experiment." (Interview)

During observations, Ferhat focused on definition and unit of density, calculation of substances' density, and comparison of immiscible liquids' density. Similar to Ayşe, Ferhat did not have experiment done in his teaching. In conclusion, both teachers focused on curricular objectives which are related with definition of density, calculation of substances' density, and comparison of immiscible liquids' density; however, teachers did not conduct experiment in their lesson. Moreover, teachers did not focus on the curricular objective that was related with the relation between Lake Ecosystem and density of water. This shows that teachers thought density as sub-topic of physics.

When vertical relations (i.e., topics taught in different grade levels related with density) were asked; Ayşe stated that density topic was related with buoyancy (8^{th} grade), phases of matter (4^{th} grade) and properties of matter (e.g., volume-mass) (4^{th} grade).

R: "Which topics not taught in the 6^{th} grade are related to the density topic?"

Ayşe: "8^{th} grade's Buoyancy force, 4^{th} grade's volume and mass (properties of matter) and different density of different states of same matter are related with density topic." (Interview)

In addition to interviews, Ayşe connected density topic to many science and math topics during observations. Topics that Ayşe referred as evidence for vertical relations in density teaching were: "buoyancy force (8th grade), states of matter (3-4th grade), properties of matter (4th grade), mixtures (4-7th grade), decimal representation of rational numbers (7th grade) and ranking of rational numbers (7th grade)".

Vertical relations that Ferhat reported in interviews were "buoyancy (8th grade), separation of mixtures (7th grade), and properties of matter (4th grade)". Ferhat's ideas are as follows:

> Ferhat: "Buoyancy force taught in 8th grade, separation of mixtures topic taught in 7th grade and volume and mass topics taught in 4th grade level are related with density."

During observations, Ferhat mentioned science and math topics that are taught in different grade levels. Vertical relations that Ferhat stated in his density teaching were "volume and mass (4th grade), buoyancy force (8th grade), mixtures (4-7th grade), line graph (7th grade) and ratio and proportion (7th grade).

Another sub-component of teachers' knowledge of curriculum is horizontal relations (i.e., topics related with density taught in same year). Regarding horizontal relations, Ayşe stated that speed topic is related with density. Ayşe's ideas are presented below:

> A: "Which topics taught in 6th grade level are related to density topic?"
>
> Ayşe: "We divide distance to time to calculate speed. Similarly, we divide mass to the volume to calculate density. When we show division in calculation of density, we mention calculation of speed." (Interview)

During observations, Ayşe mentioned "speed", "particulate nature of matter", "ratio", and "relation between division and rational numbers" as horizontal relations.

On the other hand, Ferhat, in interviews, reported that particulate nature of matter topic linked to density as horizontal relations. Ferhat's ideas about horizontal relations are presented below:

> Ferhat: "Density topic is the extension of particulate nature of matter. First, we teach matter is composed of atoms. For example, I tear the paper and the smallest part is still paper. We start with this example to particulate nature of matter." (Interview)

During observations; Ferhat linked density topic into "speed", "particulate nature of matter", "calculation of geometrical objects' volume" and "ratio" topics as horizontal relations.

Whether teachers taught knowledge beyond the curriculum was also investigated in observations. Ayşe did not provide knowledge beyond the curriculum. On the other hand, Ferhat taught knowledge beyond the curriculum in density teaching. For example; Ferhat gave an example of decrease in a substance's density (Ferhat compared an iron and iron ship in his example. Accordingly, small iron sinks in water, but huge ship constructed from iron floats on water. Then, Ferhat said that volume of iron increases too much in construction of iron ship, but mass of iron does not increase in same extent. In conclusion, Ferhat said that disproportional increase of object's volume causes a decrease of its density even though substance is same.). However, curriculum suggested that density of an object is constant. Hence, Ferhat provided knowledge beyond the curriculum. Similarly, when Ferhat showed the relationship between mass-volume and density, he focused on line graph in his teaching. However, line graph topic is suggested to be taught in 7th grade according to middle school mathematics curriculum. Hence, focusing on line graph in density teaching seems to be knowledge beyond the curriculum. Teachers did not provide further knowledge beyond the curriculum. When they made vertical relations between 7-8th grade topics and density, they did not emphasize these relations.

For example; Ayşe linked buoyancy with substance's position in liquid, but she said that: "You will learn much about buoyancy force in 8^{th} grade." Then, she did not provide further information about buoyancy force.

Lastly, sources that teachers used in density teaching were asked regarding knowledge of curriculum. Teachers reported they used textbook and workbook. Consistently, teachers used these sources in density teaching. For example; Ferhat used equal arm scale visual found in textbook showing a balance between two arms one of which has 1 kg iron and one of which having 1 kg cotton to show substances in arms have same mass, but different density. Teachers' ideas about sources used in density teaching are as follows:

R: "Which sources do you use when you teach density topic?"

Ayşe: "I use workbook and textbook to teach content. Before semester we make annual plan. We determine when and how we use textbook. Moreover, we have obligation to obey curriculum, therefore, we use textbook." (Interview)

Ferhat: "I use textbook and workbook to follow curriculum. I do not use specific source to teach density." (Interview)

Knowledge of Students' Understandings (i.e., Knowledge of Learner): Teachers' knowledge of students' understandings is summarized in table 7:

Table 7. Teachers' Knowledge of Students Understandings

Teacher	Requirements for Learning	Students' Difficulties	Causes of Difficulties	Misconceptions
Ayşe	Properties of matter Mathematical knowledge Ability to measure mass and volume States of matter Particulate nature of matter Proportion	Constancy of object's density while mass changes	Abstract nature of density Rote learning of density definition Mathematical operations	
Ferhat	Properties of matter Calculation of volume Particulate nature of matter Ratio	Volume-density relation	Inability to observe particulate nature of matter	Heavy objects sink

To uncover teachers' knowledge of learners, firstly students' requirements for learning density topic was asked. In interviews, Ayşe stated that students who knew the properties of matter, who measured volume and mass, and who had mathematical knowledge to calculate density were able to learn density topic.

R: "What are the students' requirements for learning in density topic?"

> Ayşe: "Students need to know definition of matter. They also need to know unit of mass and volume. Likewise, students are supposed to know measuring volume and mass. Apart from these, students should be good at mathematics because we expect them to find mass per volume when calculating density." (Interview)

In addition to interviews, Ayşe mentioned "states of matter, particulate nature of matter and proportionality constant" as requirements for learning density topic in observations.

Ferhat stated that knowing properties of matter topic is prerequisite to learn density. Ferhat's ideas about requirements for learning are given below:

> Ferhat: "We expect students to know mass and volume (properties of matter) topics to learn density. As well as mass and volume knowledge, if we provide daily life examples and if students are familiar with examples, students learn density easier." (Interview)

Ferhat also mentioned "calculation of volume, particulate nature of matter, and ratio" topics are requirements for learning in observations.

Next, students' difficulties that they have while learning density topic and causes of these difficulties were asked to teachers. According to Ayşe; abstract nature of density, rote learning of density definition, and mathematical expressions found in density (d=m/v) makes this topic difficult and therefore students have difficulty in understanding density.

> R: "What are the difficulties of students when they learn density? If they have difficulties, what could be causes of these difficulties?"

> Ayşe: "Density is an abstract topic. They [students] could not directly observe density. Therefore, we give examples about solid, liquid and gas phases of same matter to concrete their [student] view about density…Moreover, definition of density leads students to rote learning because when we define density, we say that density is the mass of unit volume. Moreover, students deal with mathematical operations which make the topic harder to learn." (Interview)

Observation records showed students had many difficulties in density topic. For example, students had difficulty in understanding "mass measurement, measurement of geometrical objects' volume, unshaped objects' volume measurement, relationship between mass and volume, and constancy of density when mass changes" topics. However, students' misconceptions about density topic were not identified in Ayşe's teaching.

Ferhat stated that students might have difficulty when they connect the relationship between volume, mass and density. According to Ferhat, students do not understand density because students could not observe particulate nature of matter in macro level.

> Ferhat: "There are empty spaces in substance, and some substances have more empty space. Students think superficially because they do not think what happens in sub-micro level. Therefore, students may have difficulty when learning density… Students may have difficulty when thinking on why objects have different weight even though they [objects] have same volume which is an example about students' difficulty in density." (Interview)

Examples of students' difficulties, which were revealed in Ferhat's class, are "definition of density, relationship between volume and density, sinking of small objects, relationship between mass and volume, calculation of density." Moreover, there were many misconceptions identified in Ferhat's class during observations. Some of these misconceptions are: "Heavy objects sink in water.", "Objects having spaces do not sink.", and "Volume and space are same things."

Knowledge of Assessment: Teachers' knowledge of assessment is summarized in table 8:

Table 8. Teachers' Knowledge of Assessment

Teacher	What to assess	How to assess	When to assess
Ayşe	Content knowledge (e.g., calculation of density)	By questioning Low level questions (e.g., what does measure mass?) High level questions (e.g., Different states of matter have different density, what is the reason of this situation?)	At the beginning of the lesson to reveal prior knowledge Throughout the lesson by questioning At the end of the lesson through general assessment questions Open ended questions (at the end of the unit)
Ferhat	Content knowledge (e.g., relationship between mass and volume)	By questioning Low level questions (e.g., What is the synonym of density?) High level questions (e.g. Although a metal coin sinks in water, why does not a metal ship sink?)	At the beginning of the lesson to reveal prior knowledge Throughout the lesson by questioning At the end of the lesson through general assessment questions Open ended questions (at the end of the unit)

Firstly, what teachers assess in density topic was investigated regarding knowledge of assessment. Teachers assessed students' content knowledge like "volume and density calculation" and "the relationship between mass and volume" in observations. In interviews, Ferhat told that he assessed the knowledge like "the comparison of different matter's density" and "the position of matters in a liquid".

R: "What do you want to assess when you teach density?"

Ferhat: "I give students visual showing objects which are in different position in the water, and I want students to compare density of objects. Likewise, I want students to compare density of different substances." (Interview)

While teachers explained how they assessed students, Ayşe said that she assessed students by questioning in her lessons, but she added that she had no specific assessment technic for density.

R: "Which assessment technics do you use when you assess students in density?"

Ayşe: "I use questioning in general, and then I write a question on board. I do not use a specific technic to assess students' density knowledge." (Interview)

It was observed that Ayşe used questioning technique in her teaching practice. When she asked questions, she preferred recalling questions corresponding to first level of Bloom taxonomy (e.g., What measures mass?) and higher level questions examining process and relationship (e.g., Different states of matter have different density, what is the reason of this?).

Similar to Ayşe, Ferhat stated that he used questioning to assess students' knowledge:

Ferhat: "When I assess students' density knowledge, I use questioning. Density is an easy topic; therefore, we do not expect students to prepare project in density. I do not think that detailed assessment technics like portfolio are used in density topic. I think that questioning is sufficient as a way to assess students in density topic because density is easier than other science topics." (Interview)

In his lessons, Ferhat asked low level questions requiring recalling knowledge (e.g., what is volume?) and high level questions assessing process and relationship (e.g., Although a metal coin sinks in water, why does not a metal ship sink?).

Finally, when science teachers make assessment in density topic (e.g., at the beginning of the lesson) was asked. Teachers stated that they assessed students throughout the lesson. This was consistent with the observations. At the beginning of the lesson, teachers asked questions to reveal students' prior knowledge. Questioning continued until the end of the lesson. At the end of the lesson, teachers asked questions to assess whether students reached the objectives. In exams, teachers asked open ended questions such as finding position of different objects' density in water. Teachers' ideas about when they assessed students in density topic are provided below:

R: "When do you make assessment in density topic?"

Ayşe: "I ask questions throughout the lesson. At the end of the unit, I assess students via exams. At the beginning of the lesson, I ask questions to reveal their prior knowledge. When I teach density, I ask some questions in the middle of the lesson. At the end of the lesson, I ask general questions that include all objectives." (Interview)

Ferhat: "At the beginning of the lesson, I ask questions to understand what students know about density. During the lesson, I make assessment by questioning. At the end of the lesson, I ask questions to understand whether they learn density… I do written-exams at the end of the unit." (Interview)

Knowledge of Instructional Strategies: Teachers' knowledge of instructional strategies is summarized in table 9:

Table 9. Teachers' Knowledge of Instructional Strategies

Teacher	**Subject-specific instructional strategies**	**Topic-specific instructional strategies**	
		Activities	***Representation***
Ayşe	Experiment Demonstration	Activities about objectives (e.g., Finding position of immiscible liquids comparing their density). Demonstration showing the position of objects in water Problem solving activity (e.g., density calculation problems).	Visuals (e.g.; textbook visuals) Drawings (e.g., Teacher drew figures showing the position of immiscible liquids in beaker) Examples (e.g., milk and ice cream example was shown to emphasize different states of matter have different density) Simple analogies (e.g., calculation of speed was compared to calculation of density)

Table 9. Continued

Teacher	Subject-specific instructional strategies	Topic-specific instructional strategies	
		Activities	*Representation*
Ferhat	Experiment	Problem solving activity (e.g., density calculation problems).	Visuals (e.g., textbook visuals) Drawings (e.g., graphs showing the relationship between mass and volume were drawn to board.) Examples (e.g., Examples of the objects having less density than water was said to students.) Simple analogies (e.g., teacher compared increasing density of object with the crowd of aquarium which is result of increasing fish number.)

Ayşe mentioned doing experiment regarding subject-specific strategies. Ayşe's ideas about subject-specific strategies are given below:

R: "When you generally teach science, which methods do you use?"

Ayşe: "I start with questioning to examine what students know. Based on their [students] answer, I decide to science content which I teach… Questioning and doing experiment are the methods we use in science teaching." (Interview)

In observations, Ayşe did not conduct experiment. She used demonstration instead of doing experiment. In this demonstration, Ayşe aimed to show positions of different objects in water.

Regarding topic-specific activities she conducted, Ayşe mentioned the activities which are "finding position of immiscible liquids comparing their density" and "calculating the mass, volume and density". Ayşe's explanations about topic-specific activities in density teaching were as follows:

R: "Which activities do you conduct when you teach density?"

Ayşe: "I compare immiscible liquids' density as in the comparison of water and oil. We have activities based on the calculation of mass, volume and density. I show the mass and volume of objects using different materials. I tell students how density is calculated. Students bring different objects such as eraser and wood. We throw these [objects] into the water and we observe which object sinks or does not sink in water. Based on position of objects in water, we compare the density of objects." (Interview)

Although Ayşe conducted these activities in observations, she did not support these activities with experiment. She only used demonstration in "finding the position of objects in water" activity. When she conducted density calculation activities, she used problem solving activity. However, problem solving activity was related with calculation of mathematical operations (d=m/v) instead of density topic.

Regarding representations Ayşe used in density teaching; Ayşe told she drew figures, but did not use computer to show visuals. Ayşe's ideas about representations are like that: "We draw figures, but we do not use visuals found in computer." (Interview)

Ayşe used more visuals during observations than she reported in interviews. When she started density teaching, she used textbook visual showing objects found on lake. She actively drew many figures on board throughout the lesson (e.g., figure representing the position of immiscible liquids in beaker). Likewise, she used many examples in her teaching (e.g., milk and ice cream example was shown to emphasize different states of matter have different density). Similarly, Ayşe used simple analogies in density teaching (calculation of speed was compared to calculation of density).

Similar to Ayşe, Ferhat reported that experimentation was subject-specific strategy for science teaching. However, he added he would not conduct experiment because of lack of materials in his teaching. Likewise, he did not conduct experiment in his class. Ferhat's ideas about subject-specific strategies were given below:

> Ferhat: "I start with the lesson by questioning to identify students' prior knowledge. I always ask questions not to lose students' interest in the topic. My instructions are usually teacher centred because we do not use laboratory properly. Teacher is at the centre of teaching because we have limited sources to conduct activity." (Interview)

Ferhat reported he did not conduct activity in density teaching because of lack of materials. Accordingly, Ferhat said: "Unfortunately, we do not conduct activity because of facilities. The only activity Ferhat did in observations was problem solving activity which was related with basic mathematical operations and calculation of density as in the case of Ayşe.

Regarding knowledge of representation; Ferhat stated he drew figures, but he could not sufficiently use visuals because of lack of technological equipment. Ferhat's ideas about representations are like that: "I usually draw figures on blackboard. I do not show most visuals because of technological inadequacies." (Interview)

In observations, Ferhat presented richer representations than he reported in interviews. In his teaching, Ferhat a) used visuals found in textbook (e.g., visual showing wood does not sink in water whereas marble sinks) b) drew figures (e.g., graphs showing the relationship between mass and volume were drawn to board.) c) used examples (e.g., examples of the objects having less density than water were told to students.) d) utilized simple analogies (e.g., comparison between increasing density of object and the crowd of aquarium which is result of increasing fish number.)

In conclusion, teachers' pedagogical content knowledge can be summarized like that: Teachers reported schooling, affective and subject-matter goals regarding orientation towards science in interviews; however, they focused on affective and subject-matter goals in observations. Regarding knowledge of curriculum; science teachers focused on density objectives related with physics, connected density with different science and math topics (e.g., buoyancy, ratio and proportion) as vertical and horizontal relations, and used textbook and workbook as curricular sources. While experienced teacher did not provide knowledge beyond the curriculum, novice teacher did (e.g., change of density of an object). Teachers' shared their knowledge of learner based on requirements for learning (e.g., properties of matter), students' difficulties (e.g., relationship between volume and density), and reasons of students' difficulty (e.g., abstract nature of density). Regarding knowledge of assessment; teachers focused on assessment of content knowledge (e.g., calculation of density), and they generally assessed this knowledge through questioning. Teachers aimed to assess their students throughout the lesson in terms of when to assess. Teachers reported demonstration and experimentation as subject-specific strategies. In terms of topic-specific strategies, they used problem solving activity, visuals, examples, figures and simple analogies.

Interactions among Teachers' Contextual Knowledge and Pedagogical Content Knowledge

Re-examination of teachers' contextual knowledge and PCK derived from interviews and observations revealed the interactions between these two knowledge types. According to this further analysis, four different themes emerged:

1. Teachers sometimes use their contextual knowledge to make some adjustments on their PCK:

Analysis showed that when teachers understand the constraints of context; they sometimes redesign their PCK. Accordingly, teacher could not conduct the experiment because of lack of experiment material. This is a negative situation for teachers' knowledge of instructional strategies. However, teacher made adjustment on her teaching to eliminate the negative influence of contextual factors. She replaced experiment with problem solving activity. By this way, she compensated the lack of material by using another instruction strategy (i.e., problem solving activity) from her PCK repertoire. This is an example that deficiency caused by context is eliminated by teacher's knowledge of instructional strategies, so there is an interaction between school component of contextual knowledge and knowledge of instructional strategies:

School ⟶ Knowledge of instructional strategies

Similarly, when teachers do not actively use technological equipment (e.g., internet, projector) or there is no technological equipment, teachers compensate these deficiencies by drawing many figures on board. That means, when teachers cannot show the visuals from internet, they tend to draw the figures of related visual. In this example, context negatively affects knowledge of instructional strategies because teacher could not show visuals (knowledge of representations). This deficiency is eliminated by teacher who selects another representation from her knowledge of representations. Drawings were replaced with visuals in this example to compensate negative effects of school (e.g., lack of technological equipment) and teacher (e.g., not using technology, lack of technological knowledge) components of contextual knowledge. Thus;

Teacher ⟶ Knowledge of instructional strategies

School ⟶ Knowledge of instructional strategies

Likewise, students might have difficulty in understanding density topic if their readiness level is not sufficient or they do not reach to the formal operational stage. When teachers are aware of this situation, they try to make topic more concrete. For example; teachers used ice-cream and milk example to make topic more concrete. In this example, teacher emphasized that same matter can have different densities in different stages of matter. Students who do not pass to formal operational stage can understand this concrete example. Therefore, student component of contextual knowledge informs teacher's knowledge of learner and teacher adjusts her knowledge of instructional strategies to increase students' understandings.

Student ⟶ Knowledge of Learner ⟶ Knowledge of instructional strategies

2. There are some instances that teachers 'contextual knowledge supports their PCK components:

In this study, components of contextual knowledge sometimes feed teachers' PCK. For example, past experiences and teacher beliefs, which are parts of teacher component of contextual knowledge, can support knowledge of curriculum and knowledge of learner components of PCK. Accordingly, one of the teachers believed that density is an important topic and this topic is baseline to understand other science topics. Because of its importance, the teacher claimed that he associated other science topics to density. In this example, teacher used his beliefs (teacher component of contextual knowledge) to support his knowledge of curriculum. Therefore;

Teacher ⟶ Knowledge of curriculum

Likewise, same teacher remembered his own experiences when he was a student. By this way he was able to better understand in which points his students had difficulty in density topic. Thus, his past experiences as part of teacher component of contextual knowledge supported his knowledge of learner. Therefore;

Teacher ⟶ Knowledge of Learner

3. In some situations, teachers cannot eliminate negative effects of contextual factors and their PCK is affected from this situation negatively:

In this study, it was observed that if students' readiness level is not sufficient (e.g., lack of mathematical skills), teachers could not use problem solving activity they planned and they could not solve problems regarding the calculation of density. In this situation, student component (e.g., readiness level) negatively affects teacher's knowledge of instructional strategies (e.g., problem solving) and teacher could not eliminate this negative situation. Thus;

Student ⟶ Knowledge of instructional strategies

Similar to student components, country conditions can negatively affect PCK and teachers could not eliminate these negative effects. Accordingly, science curriculum is dense in Turkey. Teachers have to teach their lessons too fast to save time for other topics, and they spend less time to teaching density. This is negative situation for their knowledge of curriculum because they do not spend enough time for teaching content. Likewise, teachers cannot conduct their planned activities because of time limitations and their knowledge of instruction is affected from this situation negatively. Therefore;

Country condition ⟶ Knowledge of curriculum

Country condition ⟶ Knowledge of instructional strategies

Likewise, it is possible that teachers' beliefs about goals of science teaching are limited because teachers have to follow national curriculum. Accordingly, subject-matter goals dominated teachers' beliefs in teaching. Teachers cannot perform their affective and schooling goals in class because there is no curricular objective revealing these goals. So;

Country conditions ⟶ Beliefs about goals of science

Teacher component of contextual knowledge can also negatively affect teachers' PCK. For example, teacher's beliefs about content (e.g., teacher believes that density is an easy topic) let teacher to use just some assessment technics and teacher do not tend to use alternative assessment technics like portfolio. This shows that teacher component can negatively affect teacher's knowledge of assessment.

Teacher ⟶ Knowledge of assessment

4. Observations show that teachers are affected by contextual factors positively or negatively even though they are not aware of contextual factors.

Teachers thought that density topic is related with physics more than biology, but they did not report this in interviews. Therefore, teachers may not teach the last objective of topic that is the importance of different phases and densities of water for Lake Ecosystem. This shows that even though teachers are not aware, teacher characteristics can negatively affect their knowledge of curriculum. Thus;

Teacher ⟶ Knowledge of curriculum

Textbooks found in country conditions can also affect teachers' PCK negatively or positively and teachers did not report this situation. Findings were taken from classroom observations. Accordingly, teachers connected other science topics with density topic using textbook. Likewise, they used activities found in textbook in their teaching. These two examples show that textbooks positively affect teachers' knowledge of curriculum (e.g., linking different science topics by use of textbook) and knowledge of instructional strategies (e.g., using textbook activities). Hence;

Country condition ⟶ Knowledge of curriculum

Country condition ⟶ Knowledge of instructional strategies

Even though textbook has some positive effects on PCK, it may also have negative effects on PCK and teachers do not eliminate these negative effects because they are not aware of them. For example; textbook includes some advance activities, which are example of curricular violation (e.g., 7th grade topics like line graphs taught in math lesson). When teacher used these activities such as calculating density of objects using line graph showing mass and volume of the objects, they make curricular violation by giving advance level of knowledge and this is not suitable for teacher's knowledge of curriculum. Even though teacher is not aware, textbook can negatively affect teacher's knowledge of curriculum. Therefore;

Country condition → Knowledge of curriculum

Discussion

Contextual knowledge is one of the four important knowledge types that teachers are supposed to have (Grossman, 1990). However, PCK dominated the studies about teacher knowledge because this type of knowledge represents knowledge about teaching in general (Grossman, 1990; Magnusson et al., 1999). Researchers proposed various models to reveal, analyze and understand teachers' PCK (e.g., Fernandez-Balboa & Stiehl, 1995; Park & Chen, 2012; Park & Oliver, 2008). However, these models are classified in two categories. According to first category, teacher knowledge types are separated and these knowledge types interact and transform to a new knowledge type known as pedagogical content knowledge. The models supporting the view of discrete teacher knowledge types and their transformation to PCK are transformative models (Gess-Newsome, 1999). Transformative models need to explain how different knowledge types are transformed into PCK. However, there is no available explanation about this transformation (Kind, 2015). On the other hand, second category about PCK models is integrative models and PCK is the sum of other knowledge types. Thus, PCK is not a new knowledge type. According to integrative models, when PCK is analyzed other knowledge types can be identified and they do not lose their meaning (Gess-Newsome, 1999). For example, it is possible to find content knowledge, pedagogical knowledge and contextual knowledge in PCK (Gess-Newsome, 1999). The deficiency of integrative models is they do not provide any explanation about how PCK is formed. For example; every teacher having some degree of pedagogical, content and contextual knowledge can automatically form their PCK; but this is not sufficient to understand nature of PCK and its formation.

Findings of the current study might assist our understandings about nature of PCK. A transformative model, which is Magnusson et al.'s (1999) model was adopted in this study. Accordingly, five components of PCK are completely different from contextual knowledge components. At the end of the study, different interactions between contextual knowledge components and PCK components were identified and four themes were formed based on these interactions. These four themes can be used to explain transformative models' mechanism that is missing, but expected to explain how different knowledge types are transformed to PCK. However, findings of the study do not show that transformative models are more reliable and valid than integrative models because we had difficulty in separating student component of contextual knowledge and knowledge of learner component. In this study, we accepted that PCK is topic-specific (Veal & MaKinster, 1999) and we believed that knowledge of learner just included topic-specific or density related prior knowledge, student difficulties and their misconceptions in density topic. On the other hand, we thought that other students related factors like their readiness level (e.g., students do not reach the formal operational stage) and student characteristics (e.g., student interest towards lesson) are part of student component of contextual knowledge. However, other research teams might accept that all student related things (e.g., misconceptions, readiness level) are part of knowledge of learner component of PCK. Therefore, it could be said that there is an interception between student component of contextual knowledge and knowledge of learner component of PCK, so PCK and contextual knowledge cannot be separated. If we did not separate these two knowledge types, we would support the idea that integrative models are more reliable and valid than transformative models.

In this point, our aim is not to decide whether transformative PCK models or integrative PCK models are true. On the other hand, we prefer a pragmatic approach as Kind (2015) did. Accordingly, we would like to benefit from the four themes revealed as a result of interactions between contextual knowledge and PCK. Therefore, these themes might assist our understandings about contextual knowledge, PCK and their interactions:

1. Teacher's contextual knowledge assists them to make adjustment on their PCK:

Findings showed that teachers' contextual knowledge informs teachers about the conditions (i.e., contextual factors including school environment, students, classroom, and community). Then, teachers' make adjustments on their PCK based on this information. Teachers did not conduct experiment in density teaching that was disadvantage for teachers' knowledge of instructional strategies because of lack of materials in their classes; then, teachers replaced experimentation with problem solving activity having same content with experiment to compensate the negative effects of lack of materials. Similarly, deficiency of technological equipment caused teachers to change their instructional strategy. Teachers reported that they could not show many visuals because of lack of technological devices (e.g., projector), which was disadvantage for knowledge of instructional strategies. Then, teachers drew many figures to show the visuals that decreased the negative effects of lack of technological materials regarding showing visuals. Fernandez-Balboa and Stiehl's (1995) views supported this situation. They stated that teachers plan to use an instructional strategy to increase quality of teaching; however, classroom conditions are not always suitable to use planned instructional strategy. Then, teachers having rich PCK are expected to select an instructional strategy, consistent with class conditions, from their PCK repertoire. By this way, teachers could not select ideal instructional strategy, but they select the most appropriate instructional strategy consistent with real conditions to facilitate students' learning.

This finding is consistent with general expectation regarding how teachers should use their contextual knowledge in formation of PCK. Grossman (1990) claimed that teachers should consider students, school, community and conditions and then make adjustment on their teaching. Likewise, Feldman and Herdman (2015) advocated that teachers should know all the people in teaching environment, school, community, topics, grade levels, country expectations regarding their contextual knowledge and they claimed that teachers should know that contextual knowledge is affected by ethical, political, economic and social factors. This shows that there is no ideal learning and teaching environment, teaching is not isolated from context and relevant conditions influence teaching (Feldman & Herman, 2015).

2. Contextual knowledge supports PCK in some situations:

Investigation of teachers' contextual knowledge and PCK showed that contextual knowledge supports teachers' PCK in some situations. For example, teachers' views about topic (contextual knowledge-teacher component) supported teachers' knowledge of curriculum. Ferhat thought that density was one of the key topics in science. His ideas about the centrality of density topic in science let him to connect this topic with many different science topics by increasing his knowledge of curriculum. Likewise, teacher experience (contextual knowledge-teacher component) fed teachers' knowledge of learners. For example, Ferhat said he had same misconceptions that his students held in his own studentship. These experiences made Ferhat knowledgeable in which point his students had difficulty in learning density. Likewise, Avraamidou (2013) reported teachers' past experiences from their own student years positively affected their orientation towards science. In her study, pre-service teachers stated they wanted to use experiences they had in science courses in their own lessons too. Likewise, Kind (2015) mentioned amplifiers of the PCK in Consensus Model, but she added that there is not enough study showing evidence for these amplifiers. Findings of this study show that contextual knowledge supports PCK and can be used as evidence for amplifiers of PCK and these findings can be used to increase explanatory power of Consensus Model in future studies.

3. In some situations, teachers cannot eliminate the negative effects of contextual factors:

Findings showed that lack of materials negatively affects more than one PCK components. For example, teachers did not conduct experiment because of lack of materials and so they did not teach objectives related with science process skills (e.g., students design experiments, measure the density of objects) in their lesson. This example shows that lack of materials negatively affects science teachers' knowledge of instructional strategies and knowledge of curriculum. There are other PCK studies showing that lack of materials negatively affects teachers' PCK (Aydın et al., 2010; Bartos et al., 2014; Cutter-Mackenzie & Smith, 2003; Lee & Luft, 2008; Rollnick et al., 2008). Similar to schools' lack of materials, district, student and teacher components of contextual knowledge might negatively affect science teachers' PCK. Regarding student component of contextual knowledge; teachers reported that they do not conduct problem solving activity in density teaching if students have difficulty on doing mathematical operations. This shows that students' lack of readiness level negatively affects teachers' knowledge of instructional strategies. Likewise, teacher component may negatively affect teachers' PCK. For example, Ferhat thought that density is an easy topic, and therefore he did not want to use alternative assessment technics in his density teaching. This shows that teacher's knowledge of assessment was negatively affected by teachers' ideas about topic. Likewise, PCK can be negatively affected by district (i.e., country conditions) component. Accordingly, teachers reported that 6th grade curriculum was highly intense; therefore, teachers taught curricular content too fast in order to teach all objectives. Hence, teachers could not do some activities. As a result, intense curriculum and teachers' obligations to follow curricular program as part of district component negatively affected teachers' knowledge of instructional strategies (e.g., not doing some activities). In their pedagogical context knowledge, Barnett and Hodson (2001) criticized the obligation of obeying curricular program because curricular programs are prepared based on ideal conditions, which are independent from contextual factors. However, real classes are not ideal environments. Therefore, teachers should have autonomy in their teaching. Thanks to this autonomy, teachers adjust curricular programs based on students' different needs and teachers provide better learning environment (Barnett & Hodson, 2001). These examples that limit teachers PCK are reported as "filters" in Consensus Model (Kind, 2015). Accordingly, teachers may use their ideas, student characteristics, and conditions they live in as filters. Because of these filters, there is always difference between their planned PCK and enacted PCK. These filters or obligatory constraints negatively affect teachers' PCK components and teachers could not eliminate these negative effects.

4. Contextual factors affect teachers PCK positively or negatively although teachers are not aware of contextual factors:

Although teachers did not consciously or unconsciously report some contextual factors affecting their teaching in interviews, observations showed that these contextual factors affect teachers' PCK. Accordingly, teachers, in interviews, did not mention textbooks' (district component of contextual knowledge) effect on teaching; however, observations showed that textbook had both positive and negative impact on teachers' PCK. For instance, textbook examples supported teachers' knowledge of instructional strategies. Likewise, connections between topics found in textbook supported teachers' knowledge of curriculum. Similarly, Arzi and White (2007) reported that teachers' content knowledge consistently develops with textbooks and textbooks are important sources for development of teachers. However, textbooks did not always positively affect teachers' PCK. For example, some activities found in textbook were related with higher grades' topics (e.g. line graph). Teachers who did these activities provided knowledge beyond the curricular program. In other words, irrelevant activities of textbooks may negatively affect teachers' knowledge of curriculum. Likewise, it is possible that teachers did not teach the density objective about biology and it could be related with their idea that density is related with physics more than biology, but teachers did not provide information about this issue. Therefore, even though teachers do not report some contextual factors affect their teaching, these contextual factors still affect their teaching. At this point, following question can be asked: Even though teachers do not have sufficient contextual knowledge, contextual factors still affect teaching negatively or positively, then to what extent having advanced contextual knowledge is meaningful? Answer of this question can be related with whether contextual factor affect PCK negatively or positively because if contextual factors affect PCK positively as in the textbook example, teacher's PCK enriches and quality of teaching increases although teacher is not aware of contextual factor. Therefore, teacher does not have to have advanced contextual knowledge. On the other hand, if contextual factors affect PCK negatively or they act as filter for teaching and teacher is not aware of the contextual factors, teacher's contextual knowledge might gain importance. Because contextual factors' negative effects can be eliminated only when teachers are aware of the problem. In other words, awareness about contextual factor (i.e., having advanced contextual knowledge) is prerequisite to ameliorate the problems caused by contextual factors. Otherwise, negative effects of contextual factors cannot be eliminated when teachers do not have advanced contextual knowledge. In conclusion, it is believed that teachers should be aware of the contextual factors that affect their teaching negatively and they should adjust their teaching by considering negative effects of contextual factors in order to increase quality of teaching.

Suggestions and Limitations

In this study, science teachers' contextual knowledge, pedagogical content knowledge and the impact of contextual knowledge on pedagogical content knowledge was investigated based on sociocultural perspective. Findings showed that science teachers' contextual knowledge play important role in shaping pedagogical content knowledge.

This study has some limitations. Firstly, some of the observational data were not recorded because video camera was not allowed to use. Secondly, findings of the study are limited with theoretical frameworks used for PCK and contextual knowledge. Thirdly, assertions are limited with density topic, public school and two teachers attending to study. It is necessary to note that findings of this qualitative study cannot be generalized to other situations; however, teachers working in similar context can benefit from the findings of the study. Moreover, this study included contextual knowledge and PCK, but other two knowledge types forming PCK, which are pedagogical knowledge and content knowledge were excluded from the study. Removing these two knowledge types from the study might inhibit comprehensive explanation of the interaction between contextual knowledge and PCK. Another limitation of the study is the lack of post-interviews with teachers because results obtained from observations are researchers' inferences. Teachers' reasoning was taken from participants after observations. At this point, Gess-Newsome (2015) advised to conduct post-interviews after observations to better understand teachers' PCK. Therefore, lack of post-interviews can be seen as another limitation of the study. However, although there are no post-interviews held with teachers, data obtained from observations shared with teachers for member check and to increase trustworthiness of the study and teachers confirmed the data. This situation can be used as evidence supporting observation results. Final limitation of the study is regarding participants' characteristics (i.e., gender and experience level). In this study, we used convenient sampling and studied with one public school and we used criterion sampling and studied with teachers working in 6^{th} grade level. As a result of this process, we had two participants who differed in their gender and experience level. It is known that gender and teacher experience could affect their contextual knowledge and PCK, so these characteristics might affect their knowledge. Researchers might fix these characteristics that affect teacher knowledge by adding new criteria for their participant selection (e.g., same gender, experience level) to better understand the interaction between contextual knowledge and PCK. On the other hand, novice male teachers can benefit from the findings of Ferhat and experienced female teachers can benefit from the findings of Ayşe if their context is similar to this study's context.

This study has some suggestions for science teachers, related institutions, the ones who are responsible for preparation of science curriculum and textbooks, and faculties of education. Firstly, this study has suggestions for teachers. We suggest science teachers to collaborate with teachers from other disciplines because density and other related science topics include knowledge from other disciplines like mathematics. Accordingly, students are expected to know mathematic topics, which are ratio and graphs. If science teachers prepare themselves to density topic by studying with mathematics teachers, science teachers can better learn teaching related mathematical knowledge to their students. Secondly, it was observed that 6th grade students usually did not develop abstract thinking and they had difficulty in understanding density that is an inferential concept. Therefore, we suggest science teachers not to use abstract and complex examples in their density teaching and we advise them to use concrete examples in their explanation. Thirdly, it was observed that science teachers taught objectives related with content knowledge in their density teaching and they ignored other important parts of scientific literacy including science process skills and nature of science. Therefore, we advise science teachers to teach other important themes like process skills in their teaching and measure students' developments in these themes. Fourthly, participants of the study used problem solving activities in this study, but their problems are based on basic mathematical operations and they ignored core ideas of density. Therefore, we advise science teachers to construct their density related problems based on daily life issues. Lastly, this study showed that teacher beliefs are highly important on PCK. Accordingly, if teachers think that topic is important, they relate topics with other science topics and they develop their knowledge of curriculum. Hence, we advise science teachers not to have bias or negative attitudes towards the topic and we suggest them to care about the content for better teaching.

We also have suggestion for the institutions responsible for ameliorating the school conditions. Firstly, we advise that schools should have more science experiment materials. If more materials are provided to schools, science teachers can conduct experiments in their teaching. By this way, they both enrich their PCK and consider the science process skills used in science experiments.

Current study also has suggestions for institutions that prepare science curriculum in middle school level. Firstly, we advise that numbers of science content should decrease because teachers just focus on transmitting content knowledge (i.e., subject-matter goals) when there is too much science content in curriculum and they do not perform their schooling and affective goals. This situation not only limits their goals, but also forces teachers to use direct instruction and they do not use other instructional strategy or methods. So, dense curriculum negatively affects both teachers' beliefs about goals of science teaching and knowledge of instructional strategies. Next, we advise the institutions that prepare curriculum for elementary school, middle school, high school and undergraduate programs to produce enjoyable science activities. Because this study showed that teachers' past experiences from their own student years supported their PCK. For example; a teacher reported that his past experiences that he gained when he was student assisted him to understand students' difficulties, which increased knowledge of learner. This study also suggested that textbooks are important sources for implementation of PCK. Accordingly, teachers improve their knowledge of curriculum by using connections between science topics given in textbooks. Likewise, science teachers enrich their knowledge of instructional strategies by using activities provided from textbooks. Similarly, teachers can shape and develop their knowledge of assessment by using exercises given in workbooks. Because of this importance of textbooks on PCK, we think that institutions should pay more attention to the preparation of textbooks. For example, textbooks can include more connections between science topics, various science activities, explanations, analogies, and alternative assessment technics. Moreover, experts from different disciplines (e.g., mathematics and science) can collaborate when science textbooks are prepared because when we collected data, science textbook included information about line graph and this topic was taught in 7th grade math lesson. This caused students not to understand related content because they were not familiar with line graph.

Education faculties can also benefit from the findings of the study. For example, experienced teacher did not provide advance level knowledge in her teaching, but novice teacher provided advance level knowledge that is curricular violation and not well for knowledge of curriculum. Therefore, it can be inferred that knowledge of curriculum aligns with experience. Because of the same reason pre-service teachers do not have experience and their knowledge of curriculum is not developed. In this point, education faculties can provide some facilities for pre-service teachers to improve their knowledge of curriculum. For example, curriculum related courses including the philosophy of curriculum, curricular objectives, connections between different science topics, advance level of knowledge that extend grade level can be provided to pre-service teachers. By this way, pre-service teachers could develop their knowledge of curriculum even though they do not have enough experience.

Lastly, professional development programs can be planned and conducted based on the findings of the study. It was observed that science teachers did not use alternative assessment technics in their lessons and this can be caused by both teachers' beliefs about topic as explained in the results section or this could be related with teachers' lack of knowledge about alternative assessment technics. Therefore, professional development programs about alternative assessment technics can be developed for science teachers. Likewise, teachers should have an instructional strategy pool and they should select suitable strategy considering contextual factors. The more instructional strategy they know, the better they adapt to different learning environments. Therefore, professional development programs can be prepared for teachers to develop their instructional strategies. In this study, teachers mainly used direct instruction. Through professional development programs, teachers can learn student centred strategies (e.g., argumentation) and their knowledge of instructional strategies might enrich. Moreover, professional development programs can be used for teachers to initiate thinking from interdisciplinary perspective. For example, participants linked the density topic with physics and they did not think biology aspect of density and they did not cover biology related objective in their lessons. Therefore, professional development programs prepared based on interdisciplinary perspectives can be useful for teachers to think holistically. Likewise, this study suggested that science teachers identified students' misconceptions in density, but they did not use specific methods to eliminate misconceptions. Hence, professional development programs can be prepared regarding the ways of eliminating students' misconceptions.

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Appendix 1. Pedagogical Content Knowledge Observation Form

Orientation towards Science Aim of choosing selected goal: (Friedrichsen and Dana, 2005)

Schooling goals:

Affective goals:

Subject matter goals:

Knowledge of Curriculum (Magnusson et al., 1999)

Knowledge of Goals and Objective					
Vertical Relations	Horizontal Relation	Used Time	Objectives	Modification of objectives	Curricular violations

Vertical relations:

Horizontal relations:

Objectives:

How teacher modified objectives, textbook content and textbook activities:

Curricular violations:

Knowledge of Materials

Sources Used in general	Aim of Use (general)	Sources Used specific to density	Aim of Use (specific)

Knowledge of Learner (Magnusson et al., 1999)

Prior Knowledge that teacher mentioned:

1.____

2.____

3.____

4.____

Students' Difficulties occurred in class:

1.____

2.____

3.____

4.____

Misconceptions:

1.____

2.____

3.____

4.____

Knowledge of Assessment (Magnusson et al., 1999)

What teacher assess			
NOS			
Objectives			
SPS			
Life skills			
Performance			
STS			
Attitudes			
Others...			
How teacher assess			
Traditional ways	Multiple choice item	Short Answer	Questioning
	True false question	Open ended	Matching
Alternative Ways	Journal	Peer Assessment	Vee Diagram
	Self-Assessment	Concept Map	Drawings
	Word association	KWL Charts	Concept Cartoons
	Structured Grid	Diagnostic Branch Tree	Drama
	Interview		Poster
	Portfolio	Performance	Others...
When to Assess		**Aim of Use**	
Formative Assessment (Assessment for Learning)	At the beginning of lesson During Execution At the end of the lesson	____________ ____________	
	High Level Questions Low Level Questions		
Summative Assessment (Assessment of Learning)	At the end of the unit	____________	
	High Level Questions Low Level Questions		

Knowledge of Instructional Strategies (Magnusson et al., 1999)

Subject Specific Strategies					
Project Based Learning	☐	Analogy	☐	Learning Center	☐
Problem Based Learning	☐	Laboratory Work	☐	Role Playing/ Drama	☐
Argumentation/ Inquiry	☐	Field Trip	☐	Concept Cartoon	☐
3E/5E/7E Learning Cycle	☐	Demonstration	☐	POE	☐

Topic Specific Strategies			
Topic Specific Activities			
Hands on Activities	☐	Problem Solving Activity	☐
Experiments	☐	Simulation	☐

Hands on activity:

Experiment:

Problem Solving Activity:

Simulation:

Topic Specific Strategies					
Knowledge of Representations					
Illustrations	☐	Examples	☐	Analogies	☐
Drawings	☐	Models	☐	Others	☐

Illustrations:

Drawings:

Examples:

Models:

Analogies: