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Research Article

Exploring primary school teachers' pedagogical content knowledge in science classes based on PCK model

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The aim of this study is to reveal experienced primary school teachers' pedagogical content knowledge (PCK), sub-components of PCK, and their possible interactions with science teaching. To this aim, a multiple holistic case study design was used. The research used a comprehensive PCK model consisting of 5 categories and 28 subcategories to reflect the knowledge base of teachers. Among the volunteered teachers, four experienced primary school teachers were randomly selected for research. Data triangulation, which utilizes interview, observation, and document analysis together, along with a subject matter knowledge test (SMKT) developed by the researchers, was used to explore teachers' PCKs in-depth. According to the results of the research, it was concluded that instead of making standard generalizations about teachers' PCK, explaining the situation over sub-categories and making comparisons on the basis of teacher competencies can guide our PCK understanding. Due to PCK's complexity and depth, several results were obtained in this study. One of the basis result of the study, the PCK category, in which experienced primary school teachers are the best compared to other categories, is *pedagogical knowledge* which is consistent between teachers and within each teacher's own levels of sub-categories. The weakest PCK categories of teachers were *knowledge of assessment in science* and *curriculum knowledge of science*, this situation also leads to inadequacies in using appropriate contemporary learning-teaching processes, strategies, alternative assessment methods and rubrics. Therefore, the PCK model of the research can be recommended as an explanation guide for future studies.

Keywords: Pedagogical content knowledge; Science teaching; Primary school teachers; Subject matter knowledge; Curriculum knowledge; Knowledge of assessment

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1. Introduction

Developments in social, economic, technological, and scientific fields and competitive environments also change perceptions of ideal individuals. This transformation necessitates raising individuals with many skills and competencies, especially 21st-century skills (Organization for Economic Cooperation and Development [OECD], 2017; Ministry of National Education [MoNE], 2018). This requirement places raising ethical individuals who can keep up with

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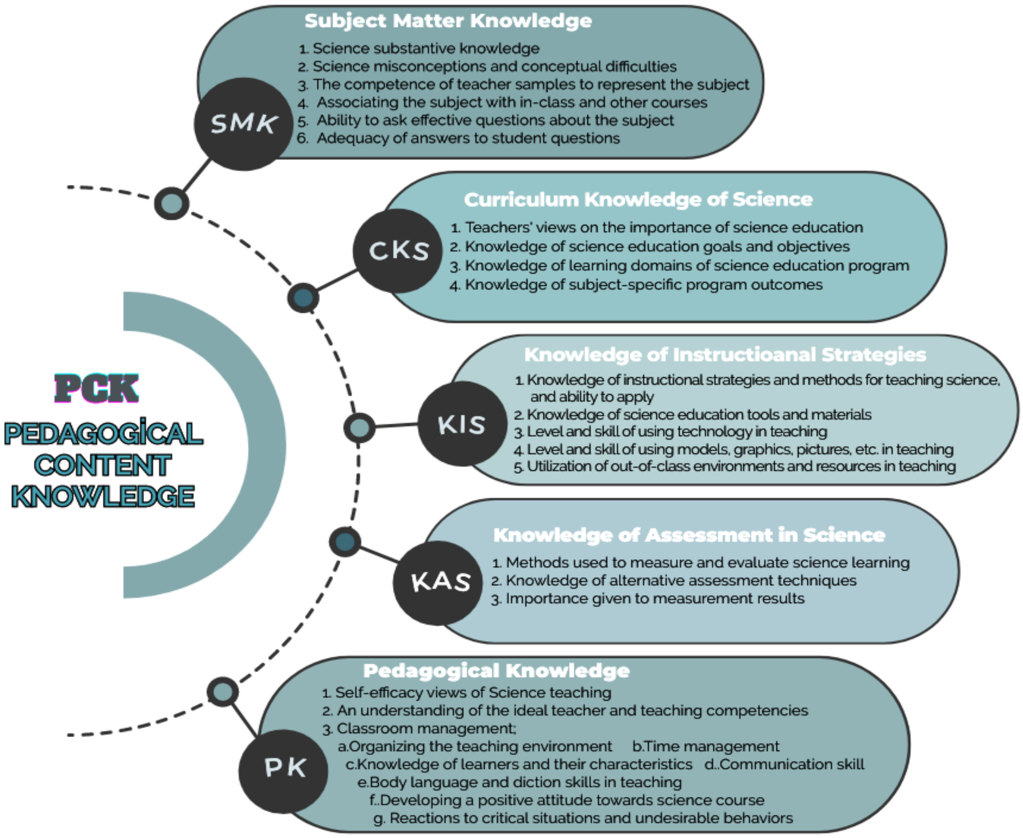
contemporary life, the 21st century or the digital world, who produce, are open to development, self-organizing and ethical among the ultimate goals (Mıhladız Turhan & Açık Demirci, 2021). Thus, in line with the increasing automation of manual-based occupations and the expanding demand for highly specialized brainpower-based occupations, a high level of scientific literacy is targeted for all students (Abd-El-Khalick & BouJaoude, 1997). The mandatory policy for teaching and learning 21st-century skills such as problem-solving, collaboration, communication, and creativity has brought along the requalification of the current teacher workforce and the upgrading of the knowledge base of the teaching profession (Guerriero, 2014). That is because the teacher, who is described as a professional person who brings the desired behaviours into the educational environment (Sönmez, 2003), has as much a key role as the student, who is the basic element for effective teaching (Balcı, 1993; Kahyaoğlu & Yang, 2007).

The conceptualization of teacher knowledge is a complex issue that involves understanding teachers' knowledge base, the teaching and learning cycle, the concept of knowledge, and how teachers' knowledge is put into action in the classroom (Guerriero, 2014). In general terms, the concepts of teacher competencies or teacher knowledge bases are specific knowledge areas that a teacher should have and are discussed under the title of "Pedagogical Content Knowledge (PCK)" in the educational research literature (Shulman, 1987). In a broader perspective, PCK is defined as using more useful formations, stronger analogies, illustrations, examples, explanations, and demonstrations for a better understanding of a subject, in other words, ways of presenting the subject in order to make it more understandable for others (Shulman, 1986). In 1987, Shulman discussed teacher knowledge base in 7 categories (Content knowledge, General pedagogical knowledge, Curriculum knowledge, Pedagogical content knowledge, Knowledge of learners and their characteristics, Knowledge of educational contexts, Knowledge of educational ends, purposes, and values). Shulman (1987, p.8) also expressed PCK as "that *special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding*". In 1988, Tamir reorganized Shulman and Sykes' (1986) teacher knowledge categories to be used in teacher education and introduced the teacher knowledge model with 6 main categories (General free education, Personal performance, Subject area, General pedagogy, Subject-Specific Pedagogical Knowledge, Fundamentals of the teaching profession). Again, following Shulman (1987), his student Grossman (1990), as well as Cochran et al. (1993), Magnusson et al. (1999), Morine-Dershimer and Kent (1999), and many other researchers later discussed PCK by explaining it through PCK models they created. Cochran et al. (1993) renamed PCK with the concept of Pedagogical Content Knowing (PCKg) to emphasize the dynamic nature of knowledge development. Magnusson et al. (1999) noted that even the knowledge and beliefs of the teachers deeply affect their teaching and other components of PCK and detailed the dimensions by including "science teaching orientations" in PCK categories. Therefore, researchers try to explain, analyse, revise or integrate PCK by modelling it with similar but also different categories and sometimes more detailed subheadings. For instance, Magnusson et al. (1999) benefited from the studies of Grossman (1990) and Tamir (1988) and examined PCK in five dimensions. Similarly, Abell (2007, p.1107) used the science teacher knowledge models of Grossman (1990) and Magnusson et al. (1999) to create a modified fundamental PCK model with several subcategories. With this awareness, Carlson and Daehler (2019) presented the Refined Consensus Model (RCM) of PCK, which consists of 3 distict realms, namely Collective PCK, Staff PCK and Enacted PCK, with the contributions and common opinions of many international science education researchers. Also RCM of PCK emphasizes the content knowledge, pedagogical knowledge, knowledge of students, curricular knowledge and assessment knowledge as the professional knowledge bases of teachers.

Likewise, our study examined some pioneering studies on PCK models (Abell, 2007, p.1107; Friedrichsen et al., 2009; Grossman, 1990; Magnusson et al., 1999; Mıhladız, 2010; Morine-Dershimer &Kent, 1999, p.23; Shulman, 1987), and structured a science teaching-oriented PCK model with comprehensive subcategories that complement each other and reflect the deep structure of teacher knowledge base for this research. The main categories and subcategories of the PCK model created in this research are presented in Figure 1.

Figure 1

The PCK model of the research with categories and subcategories for science teaching



Some situations reveal the limitations and difficulties of creating a clearly defined common language for PCK, which is expressed as teacher knowledge base or teacher competencies. Abell (2007), Hashweh (2005), Marks (1990) and van Driel et al. (1998) stated that SMK is a powerful knowledge category, but like other PCK knowledge bases, SMK alone is not sufficient for effective teaching. Although they may seem separate, PCK elements are intertwined and should be used flexibly due to common intersections between different subcategories. The more representation teachers have and the better they recognize learning difficulties, the more effectively they can implement their PCK (Van Driel et al., 1998). Friedrichsen et al. (2009) suggested that since a science teacher will have a different discipline-specific PCK than an English teacher or a math teacher, PCK should be looked at more broadly than simply from a subject-specific perspective. In this sense, PCK has become very popular in the field of science education, and many researchers have examined the knowledge and professional development of science teachers within the framework of the concept of PCK. In this process, PCK research on teachers and teacher candidates' teaching knowledge base (Abd-El-Khalick & BouJaoude, 1997; De Jong et al., 2002; Fernandez, 2014; Guerriero, 2014; Turner-Bisset, 1999), subject matter knowledge (SMK) (Ball, & McDiarmid, 1990; McEwan & Bull, 1991; Tamir, 1988; Yılmaz Yendi, 2019), content knowledge (Morine-Dershimer & Kent, 1999; Özden, 2008), teaching orientations (Avraamidou, 2013; Demirdöğen, 2016; Friedrichsen et al., 2010; Karal, 2017; Magnusson et al., 1999; Maseko & Khoza, 2021), and direct PCKs (Canbazoğlu, 2008; Cohen & Yarden, 2009; Kind, 2009; Lee & Luft, 2008; Mıhladız & Doğan, 2017; Park et al., 2011; Park & Oliver, 2008; Van Dijk & Kattmann, 2007), as well as on monitoring PCK development (Drechsler & Van Driel, 2008; Friedrichsen et al., 2009; Hanuscin et al., 2018; Van Driel et al., 1998) have entered the literature. Van Driel et al. (1998) considered sufficient content knowledge a prerequisite in science teaching, and emphasized teaching experience as the main source of PCK.

Appleton (2003) emphasized that science PCK is essential to teach science. He also noted that besides teachers who regularly teach science, the common denominator of studies on problems in primary school science education is the scientific knowledge of teachers. Accordingly, besides the teaching of science as a single field, which is quite arduous even for science teachers, knowledge and status of the primary school teachers, who teach multiple fields and are the first to introduce science to younger students, in the teaching processes became more intriguing. This situation brought with it the questions about the primary school teachers' knowledge of science, whether their experiences affect their science teaching and to what extent they dominate science programs. Scientific research that addresses PCK, which expresses teachers' interpretations and transformations of subject knowledge, as a productive model that allows teachers to understand their professional knowledge, systematize empirical data, and document and transfer ideas about relevant knowledge into teaching practice (Fernandez 2014) provides the opportunity to establish a link between research on teaching and research on learning (Van Driel et al., 1998). In this respect, it is crucial to investigate the degree and level of special abilities that a classroom teacher will use while fulfilling the great responsibility of raising science literate individuals who research and question, and whether they can use these abilities. The present study aimed to reveal experienced primary school teachers' pedagogical content knowledge and sub-components of science teaching and their possible interactions using the PCK model created for the research (see Figure 1). In this context, the sub-objectives of the research were to investigate the situation of primary school teachers on the basis of each of the five PCK subcategories: 1) subject matter knowledge of science, 2) Curriculum knowledge of science, 3) Knowledge of instructional strategies in science teaching, 4) Knowledge of assessment in science, and 5) Pedagogical knowledge in science teaching.

2. Methodology

The case study method of qualitative research methodology was used to evaluate the primary school teachers' PCK. A case study is used to analyse one or a few special cases in depth (Creswell, 1998) and provides an opportunity to record the holistic and meaningful features of real-life events (Yin, 2009, p.4). The "Multiple Holistic Case Study Design" was adopted for this research. Accordingly, each situation in the research was handled holistically and then compared with each other. In this context, the events reflecting the PCK of each primary school teacher were determined and interpreted with in-depth analysis, the findings were evaluated holistically, and the quality of the research was improved by comparing the results with other situations.

2.1. Participants

The research was carried out with 4 primary school teachers (Table 1) randomly selected from the teachers who were teaching in the 4th grade of primary school, experienced in their professions, and volunteered to participate in the research. It was assumed that they reflected their pedagogical content knowledge and natural teaching environment during the course, which was directly observed by one of the researchers.

Table 1
Demographic characteristics of primary school primary school teachers

Nickname	*Gender*	*Age*	*Type of school graduated from*	*Years of Professional Experience*	*Education Given to 4th Grades*
Arda	Male	between 50-55	Institute of Education	between 25-30	5 times
Gaye	Female	between 40-45	Faculty of Education	between 15-20	4 times
Mert	Male	between 40-45	Faculty of Education	between 15-20	5 times
Sude	Female	between 40-45	College of Education	between 20-25	4 times

After graduating from "Faculties of Education", teachers in Turkey start their duties with the national selection exam. As shown in Table 1, 2 teachers graduated from a 4-year faculty of education and had 15-20 years of experience. The other 2 teachers graduated from the Institute of Education (2 years) and the College of Education (2 years), which are systems that provided teacher education in the previous periods, and they had more work experience. Primary school teachers in Turkey provide education to young students from grade 1 to grade 4 in almost all fields, including science education. Then, starting from the 5th grade of secondary school, science teachers, who are branch teachers, enter science courses. Primary school teachers participating in the research generally taught different 4th grade students at least 4 times.

2.2. Data Collection Process

Prior to the research, a pilot study was conducted with a total of 4 experienced primary school teachers working in *4 schools other than those included in the present study.* The pilot study enabled the researchers to experience in practice the suitability of the developed data collection plan, the validity and reliability of the data collection tools, and identify potential problems. In this process, the 4-hour teaching period of each primary school teacher in the 'Let's Get to Know the Matter' unit were observed and recorded by the participating researcher. During the observations, a course "observation form" was tried to be created. In addition, three individual interviews were held with experienced teachers. Audio recordings of the interviews were taken, allowing them to be re-examined when necessary. Thanks to the pilot study, necessary changes and innovations were made for the original form taking into account the points that were not understood in the interview questions. The pilot study contributed significantly to the participant's knowledge and experience about the situations or difficulties they may encounter in the main study.

The main research was carried out with 4 experienced primary school teachers working in different primary schools. The research was conducted with experienced teachers during the teaching of "Living and non-living things" and "Living spaces" within the scope of "Exploring and Knowing the World of Living Creatures [EKLC]", the sixth unit of the 4th grade science curriculum. In accordance with the participatory observation method, at least 5 course hours were observed by the researcher during each teacher's teaching of science subjects, and the courses were evaluated on an observation form, as well as being video-recorded. Research data were collected through Subject Matter Knowledge Test [SMKT], interviews, observations and documents.

2.3. Data Collection Techniques of the Research

The preferred qualitative research method for in-depth research of experienced primary school teachers' PCKs for science education was the *data triangulation* technique, which utilizes interview, observation, and document analysis concurrently. Observation and interview techniques enable the researchers to see the researched subject from the perspectives of the participants and the data to verify each other mutually and jointly. Diversification, on the other hand, contributes significantly to the validity and reliability of the research by enabling the evaluation and interpretation of the results in different dimensions (Yıldırım & Şimşek, 2008). In addition, considering that teachers embody their PCKs in the process of their teaching arrangements, conceptualization of PCK using interviews reflecting teachers' knowledge and opinions, teaching observations in the classroom (Hanuscin et al., 2018) and a test of their subject knowledge makes teachers' PCKs more understandable.

2.3.1. Subject Matter Knowledge Test (SMKT)

SMK, one of the basic elements of PCK, is of great importance for reflecting the knowledge levels, misconceptions or misinterpretations and dominance of the subject area of the teachers who will plan, manage and guide the teaching process. In this sense, SMKT was applied to the participating primary school teachers for the EKLC unit. The SMKT was developed by the researchers based on the relevant literature review and cooperation with the subject area expert. The first version of the test was applied to a total of 152 primary school teacher candidates in the pilot study. As a result of the analysis made with the SPSS15 statistical software package, 11 items affecting the validity and reliability were excluded from the test. The Cronbach's alpha reliability coefficient was determined as .73, and the finalized subject area knowledge test consisted of 3 main parts. The first part included 23 multiple-choice test questions and a field for teachers' reasons for choosing this option at the end of each question. The second part consisted of 22 true-false questions, and the third part consisted of 9 open-ended questions. The prepared test was applied to 4 experienced teachers to obtain information about their SMKs before teaching.

2.3.2. Data Triangulation

According to Patton (2002), the purpose of the interview is to enter an individual's inner world and understand his/her point of view. In order to obtain detailed data, three interviews were held at the beginning, middle and end of the study. Audio-recorded interviews were arranged as semi-structured. Within the scope of PCK model elements of the research, a total of 20 questions were asked to each of the primary school teachers, 8 in Interview I, 7 in Interview II, and 5 in Interview III. Participant observation was carried out by one of the researchers during the science courses of experienced primary school teachers. The teaching processes of the teachers in the EKLC unit were documented by the researcher through audio video recording and filling in the course observation form. The observation form developed to be used for lesson observations during teachers' teaching process consisted of 5 dimensions. The form covered 6 features in the SMK dimension, 27 in the PK dimension, 16 in the KIS dimension, 38 in the CKS dimension and 23 in the KAS dimension. The participants' status of having these characteristics was rated as 'sufficient, insufficient, partially sufficient', 'yes, no', 'yes-no'. The documents consisted of textbooks, evaluation forms, exams, meeting minutes, students' homework and research presentations, trip plans, audio recordings of teachers' interviews, audio and video recordings of observations, and their written texts.

2.4. Data Analysis

For the multiple-choice questions in the first part and true-false questions in the second part of the SMPT developed for the research, 1 point was given to teachers who gave "correct answers" and 0 points to teachers who gave "incorrect answers" or left blank. Teachers were also asked to explain their reasons for choosing the options in the questions or explain their answers. “Rubric” was used to evaluate the explanations of the teachers about the answers given in the first and second parts, and the answers given to the 9 open-ended questions in the third part. In the developed Rubric, the teachers' "correct", "incorrect" or "explaining in accordance with scientifically accepted ideas" were scored with the consensus of the researchers, with a rating of 0-5 points. For example, presenting "an incorrect concept but a scientific explanation" was given 2 points, while "a correct concept and a scientific explanation" was given 5 points.

Descriptive and content analysis was performed in the research. In the descriptive analysis, the findings are presented in themes, and the opinions of the individuals interviewed or observed are included with direct quotations. The aim here is to present the findings to the reader in an organized and interpreted form (Yıldırım & Şimşek, 2008). Content analysis, on the other hand, aims to reach concepts and themes that are not noticed in the descriptive approach through an in-depth examination of the data. The NVivo 8 software was used for data analysis, with the codes of Mıhladız's (2010) PCK subcategories to assess the skill levels of primary school teachers. Teachers' expected skills were graded as "*Quite sufficient, High, Sufficient*" for high-level skills, "*Partly High, Partially Sufficient*" for moderate skills or skills with deficiencies, and "*Low, Insufficient*" for no skills or misconceptions. This code list created by the researcher and the consultant was used to evaluate 25% of the interview data. The cases where the researcher and the consultant used the same code for the data were accepted as consensus, and the cases where they used different codes were accepted as disagreements, and the reliability of the research data analysis was calculated using the formula 'Consensus / (Agreement + Disagreement) x 100' (Miles & Huberman, 1994). Based on this calculation, the average reliability in data analysis was determined as 80%.

3. Results

The results of the present study are given on the basis of the research's PCK model presented in Figure 1, and the sub-problems are explained in order. The subcategories of each PCK category and the teachers' status in this category are presented in the relevant tables. For the relevant PCK subcategory, the fields in which repetitive and significant findings from the teachers could not be obtained are indicated with a hyphen (-). In addition, after each table, the subcategories in the table are shared under the headings, supported by table explanations, comments and quotations. Quotations of 4 participating primary school teachers during the interviews and teaching are given under code names (Arda, Gaye, Mert and Sude). Abbreviations are used in quotations about students, S for a single student, S1, S2, S3… for each of more than one student. Each interview quotation is followed by the number of interview the quotation belongs to and the line spacing of the interview text in parentheses (e.g., Interview #1, 19-24). Quotations from the course observation are followed by which course observation the quotation belongs to and the minute and second interval of the observation record (e.g., Course Observation #3, 19:27-20:23).

3.1. Primary School Teachers' SMK Results

Unlike the other PCK categories of the research, the SMK category utilized SMKT in addition to interviews, observations, and documents. Here, the aim was to reveal the knowledge levels of teachers about the unit "Exploring and Knowing the World of Living Creatures" in the science course. Table 2 shows the sum of the primary school teachers' scores from the SMKT, as well as the scores they got from the explanations for each test question they marked and answered.

Table 2

SMKT score distribution of experienced primary school teachers

Quest. Types	*Multiple Choice Questions*			*True-False Questions*			*Open-Ended Questions*			*TEST Total Score*		*Explanation Total Score*
	Correct	Incorrect	Empty	Correct	Incorrect	Empty	Correct	Incorrect	Empty	Correct	Incorrect	
Arda	11	8	4	22	-	-	6	3	-	39	11	94
Gaye	19	3	1	16	-	6	7	1	1	42	4	249
Mert	17	3	3	22	-	-	8	1	-	47	4	133
Sude	18	5	-	20	1	1	6	-	3	44	6	234

As seen in Table 2, Mert answered the questions most correctly in the test about the living creatures unit of the Science course, Sude followed with close results, and Arda had the lowest number of correct answers. The maximum score that could be obtained through the explanations of the items marked by the teachers in the test was 324. Gaye wrote the most scientific and appropriate explanations and answered the items more consciously and with a higher level of content knowledge. Sude had average success in the group, and Mert gave weaker scientific explanations.

Besides the SMKT results, the level of Subject Matter Knowledge, which is one of the categories that will reveal the PCKs of teachers, was also evaluated through detailed interviews and observations on the basis of 6 subcategories (Figure 1), and the findings are presented in Table 3.

Table 3 shows that primary school teachers differ in the 1st and 2nd subcategories, which are the indicators of SMKs, but they have similar levels in the other 4 subcategories. Detailed information on the status and levels of teachers in 6 SMK subcategories, comparisons and explanations through course observations and quotations from interviews are presented below.

3.1.1. Teachers' science substantive knowledge

The findings of primary school primary school teachers' "Science Substantive Knowledge" are presented in Table 3 as the 1st SMK subcategory. One of the most important and substantive science subjects in which teachers' content knowledge is questioned on the basis of "EKLC" in primary school science course 4th grade unit is germination. The subject of germination includes

Table 3
Primary school teachers' competencies in SMK subcategories

	Arda		*Gaye*		*Mert*		*Sude*	
	Interview	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*
SSK	High	High	Low	High	High	High	Moderate	-
SMCD	-	Misconception	-	-	-	Misconception	-	Misconception
SRS	-	Sufficient	-	Sufficient	-	Sufficient	-	Sufficient
AS	-	Quite Sufficient	-	Quite Sufficient	-	Quite Sufficient	-	Quite Sufficient
AAEQ	-	Sufficient	-	Sufficient	-	Sufficient	-	Sufficient
AASQ	-	Mixed	-	Mixed	-	Mixed	-	Mixed

Note. SSK: Science substantive knowledge; SMCD: Science misconceptions and conceptual difficulties; SRS: Samples to represent the subject; AS: Associating the subject with in-class and other courses; AAEQ: Ability to ask effective questions; AASQ: Adequacy of answers to student questions.

most of the basic concepts related to plants. The teachers were asked how they could give feedback on the answers received from the students in the teaching environment, through a case study about the germination of onions. Evaluation of the teachers' content knowledge of this unit showed that the participants Mert and Arda had high SMKs and included activities related to germination in their teaching processes. During the interview, Sude stated that suitable environment, heat, light and humidity are required for germination, but did not include any activities or experiments related to germination during the course observations. Gaye's statements during the interview were not clear, but she gave more explanatory information during her teaching:

> Gaye: "… Eeeeee what could it be? It could have been watered. And saw sunlight…." (Interview #3, 544)
>
> Gaye: "So there was water and air for the seed of the dormant bean. But once the leaves come out, it also needs soil and sun... Why? So that it can make its own food." (Course Observation #5, 14:22-15:47)

Arda, Gaye and Mert had their students do experiments to examine the germination phenomenon individually or as a group.

> Mert:" Now let's bring an experiment done by our friend Yahya. Yahya, tell me what is this?"
>
> S1: A bean... I put a napkin in a jar. I put beans. I moistened a little. It wasn't out last week. There was no germination. It was a regular bean. (Course Observation #3, 11:16- 13:50)

3.1.2. Science misconceptions and conceptual difficulties of teachers

As can be seen in Table 3, Arda, Sude and Mert had misconceptions on some issues in the EKLC unit. Arda thought that the concepts of bronchus and trachea were the same. He also used the word microbe instead of the concept of microscopic creatures during the lesson. While examining the onion skin under the microscope, he used the term "microscopic creatures", referring to the cells he observed. The common misconceptions of Sude and Mert were slide and cover glass (lam and lamel in Turkish), which they were using interchangeably. In addition, Sude marked "false" for the statement "All living things breathe in the same way" in the 7th question of the second part of the SMKT, and used the expressions "Plants do photosynthesis, animals breathe" in the explanation for the reason for choosing that option. It is seen that Sude considers photosynthesis as a type of respiration but makes a distinction that photosynthesizing organisms do not perform the respiration reaction.

> Sude: "We divide creatures into two according to their respiration. Those who do photosynthesis, that is, those who take in carbon dioxide and give off oxygen, and those who take in oxygen and give off carbon dioxide." (Course Observation #4, 5:17-5:53)
>
> Sude: "Would you like to see the cell responsible from photosynthesis? For example, the cell called chlorophyll." (Course Observation #4, 17:35-17:43)

3.1.3. The competence of teacher samples to represent the subject

During the course observations, the examples given by the primary school teachers to their students on science subjects were examined and it was determined that all the participants frequently presented examples and the examples were sufficient in representing the subject. The examples given by the teachers, mostly through representative cases, were as follows:

> S: "Seeds are normally non-living, right?"
>
> Arda: "Noo. But when cooked, it loses that living feature inside, then it becomes non-living. For example, in the same way, eggs lose their reproductive properties when cooked." (Course Observation #2, 19:38- 20:25)

> Gaye: "There was a man. He carried water to his house. But, one of the buckets was punctured. He hung the one with hole in the same direction every day. After a while he saw… What do you think might have happened?"
>
> S: "There were flowers in the places where the water leaked."
>
> Gaye: "Yes..where the cracked bucket was..he saw that the plants were more alive and bushier. So,

plants also need water for their nourishment." (Course Observation #2, 0:00-1:16)

3.1.4. Associating the subject with in-class and other courses

It has been determined that teachers pay attention to making connections within and between courses many times in science courses (Table 3).

Example of associating another subject within a science lesson as follow:

S.: "We can move some of the living and non-living objects, but we cannot move some of them."
Gaye: "Yes, very nice your friend has associated it with the force unit. When we applied thrust, we were able to move some entities, but not others". (Course Observation #1, 1:33- 4:03)

Example of associating subjects between courses;

Arda:"You know, in our social activity class yesterday, we saw that as plants that grow in the local environment. (Showing the potato.) These also germinate when the necessary environment is provided for them." (Course Observation #4, 3:19- 3:41)
Mert :"If we had studied this story in social studies class.. I would say the grasshopper knocks on the ant's door. And says he will go to the hot regions and came to say goodbye" (Course Observation #5, 35:52- 40:24)

3.1.5. Ability to ask effective questions about the subject

Teachers' ability to ask effective questions about the subject, which is the 5th subcategory of the SMK category, is given in Table 3. During the course observations, it was determined that all teachers frequently used the question-answer method in their classrooms and were generally "sufficient" in asking effective questions.

Sude: Now, someone is destroying such a magnificent environment, the environment where so many creatures live? So who are they?""
S1: "Us, the people."..
Sude: "For these people.. everyone has a duty.. what should be our plus duties? What is your duty?"
S1: "Let's collect garbage, plant trees, not throw toxic wastes on the soil, warn those who pollute the environment". (Course Observation #3, 31:11- 34:06)

Gaye: "Gaye: "So if someone in your house gets the flu, do other members of the family get the flu too?"
S.: "Yesss."
Gaye: "How does this happen?"
Ö.: "It spreads. With germs."
Gaye: "Well, did you see the germs?""
S.: "No!!.When we sneeze, microbes spread into the air and reach other people." (Course Observation #6, 9:09-12:25)

3.1.6. Adequacy of answers to student questions

Since the adequacy of the answers given by the teachers varies from subject to subject, a clear generalization cannot be made for the adequacy of all the answers given to the student questions, which is the 6th subcategory of the SMK.

Examples of adequate answers given by teachers were as follows:

S: "Teacher, trees shed their leaves in autumn, how do they breathe then?"
Arda: "Does anyone want to answer this? (none) Now the leaves are falling, but there are pores on the trees, then they breathe through those pores." (Course Observation #5, 13:05-13:31)

Examples of partially adequate answers given by teachers were as follows:

S: ""When we get sick, teacher, do our medicines also contain beneficial bacteria?"
Gaye: "es, let's not say beneficial bacteria in vaccines, there are dead microbes". (Course Observation #6, 18:58-19:19)

Examples of insufficient answers given by teachers:

S: "But even if there is no soil, it can still germinate in cotton?" (Referring to the bean seed)
Mert: "It will be like that for a short time." (Course Observation #3, 25:09- 25:16)

3.2. Primary School Teachers' CKS Results

Table 4 shows the classroom teachers' status in the subcategories (Figure 1) of Curriculum Knowledge of Science (CKS) based on the 4th-grade "EKLC Unit" teaching.

Table 4
Primary school teachers' competencies in CKS subcategories

CKS Subcategories	*Arda*		*Gaye*		*Mert*		*Sude*	
	Interview	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*
1.	Partly high	Partly high	High	High	High	High	High	High
2.	Sufficient	Sufficient	Sufficient	Sufficient	Partially Suff.	Partially Suff.	Sufficient	Sufficient
3.	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient
4.	[This subcategory is elaborated in Table 5]							

3.2.1. Teachers' views on the importance of science education

As seen in Table 4, all of the primary school teachers who participated in the research had positive views on the importance of the science course. Arda thought that in this course, students learn by doing and experiencing and that it is more interesting than other courses in terms of visuality. Sude thought that with the science course, children get to know themselves, their environment and their place in nature, and this affects their perspectives on the world. Mert thought that science is open to change and has a wide range of subjects. Gaye emphasized that science course is necessary and intertwined with life and pointed out that it is connected with other courses (Course Observation #3, 28:36,4-28:49,4). Again, Gaye and Su agreed that the science course directs students to research, so they are more active.

> Gaye: "If we consider the Turkish lesson.. they use that language all the time anyway.. But a science lesson, for example, a battery subject, what does it do? Why are there (+) and (-)? .. it helps to increase their curiosity and encourages them to research." (Interview #1, 19- 24)

> Mert: "…you cannot see some stereotypes in science class. Whether they descend or go underground, they have entered every aspect of our lives. And we see that there are millions of pieces of information that can be learned from an insect or a flying bird." (Interview #1, 38- 50)

It was determined that each of the teachers, who were asked how they made their students feel science, applied different methods;

> Sude: "In the fifties-sixties, so many pesticides were used that our lands were poisoned and voles died. When the mice died, the snakes starved. Then they came to the cities to find food. They started to harm people. Scientists found that the voles decreased and were poisoned by the manure in the soil." (Course Observation #3, 19:27-20:23)

> Arda: "Your friend Alperen said one day, my teacher, I can't see. And when Alperen goes to the doctor, he gave number 2 glasses..Lenses help him to see even more living things. Likewise, here we see the creatures we cannot see with the help of a microscope." (Course Observation #4, 12:53-14:15)

3.2.2. Knowledge of science education goals and objectives

The vision of science education is to raise scientifically literate individuals. Accordingly, it was seen that all participants agreed that scientifically literate individuals should have an investigative personality. It has been determined that Gaye, Sude and Arda were individuals who were sensitive to their environment and knew their environment better, Sude was sensitive to science, and Sude and Gaye were questioning individuals. Mert defined scientifically literate individuals as those who have developed creativity, are curious, planners, put their plans into practice and want to share what they have learned.

> Mert: "..they are definitely curious and research-oriented.. ..they brought their flowers. We had students here who brought their birds and even fish chicks. So they are not empty. In other words,

they are examining nature and what is going on around them, they are curious. And they want to share this too." (Interview #1, 241- 248)

Besides, primary school teachers Arda, Sude, and Gaye have jointly emphasized the student-centred structure of the curriculum. Arda stated that activities were frequently included in the program, Sude stated that the student was asked to find the information, and Gaye stated that many experiments were included and the student was directed to research. Mert mentioned that visuality and practice are included most of the time, and instead of giving stereotypical information to the student, the student is urged to research.

3.2.3. Knowledge of learning domains of Science Education Program

In addition to the unit acquisitions in the current science curriculum, field acquisitions such as Scientific Process Skills, Attitudes/Values, and the relationship between Science, Technology, Society and Environment given under the title of learning domains are also among the important elements of the science curriculum. Gaye stated that she had read the mentioned learning domain acquisitions but did not remember their expansions. Mert stated that he did not know the expansions of these abbreviated acquisitions. Sude, on the other hand, stated that she knew some but not all of the acquisitions, but she could not explain them. Arda stated that he did not look at these achievements and did not draw any attention to them. However, during the course observation, it was noted that Arda drew the attention of the students to "the relationship between society and the environment (Course observation #4, 27:55- 28:28)".

3.2.4. Knowledge of subject-specific program outcomes

Teaching the EKLC unit requires having knowledge about the subjects and acquisitions. Table 5 shows primary school teachers' level of knowledge about a major part of the unit.

Table 5
Level of Knowledge About Acquisitions on Living and Non-living Creatures

Part of acquisitions from the unit	*Arda*	*Gaye*	*Mert*	*Sude*
1.1. Gives examples of living and non-living creatures.	Sufficient	Sufficient	Sufficient	Sufficient
1.2. Decides whether an entity is living or non-living by questioning.	Sufficient	Sufficient	Sufficient	Partially Sufficient
1.3. Compares plants and animals in terms of vitality characteristics.	Sufficient	Sufficient	Sufficient	Sufficient
1.4. Discusses whether there are small creatures that cannot be seen with the naked eye.	Sufficient	Sufficient	Sufficient	Sufficient
1.5. Observes some living things that cannot be seen with a microscope.	Sufficient	Sufficient	Sufficient	Sufficient
1.6. Makes the inference that dormant living creatures show vitality under suitable conditions.	Sufficient	Insufficient	Sufficient	Insufficient

As can be seen in Table 5, all of the teachers knew the subject acquisitions in general, except for science acquisition 1.6. However, Sude's statement 'We divide living things into mammals and non-mammals, that is, those that lay eggs..' (Interview #1, 80-83) shows that her knowledge of unit acquisitions and content knowledge in this subject is low. In fact, there is no acquisition regarding the grouping of living things in that unit. On the other hand, Arda and Mert had sufficient knowledge about the need for suitable conditions for dormant creatures to show vitality again.

S: "Seeds are normally lifeless, aren't they, teacher?"
Arda: "Noo. But when cooked, it loses that living feature inside, then it becomes non-living. Like eggs, for example. When cooked, it loses its reproductive properties. If the seed is non-living, it will not come out. For example.. a grain of wheat we throw on the soil becomes fifty grains. Why? It is alive." (Course Observation #2, 19:38-20:25)

3.3. Primary School Teachers' KIS Results

In the present study, Knowledge of Instructional Strategies (KIS) was investigated as one of the elements that make up the PCKs of primary school teachers. Findings for the 1st sub-category are shown in Table 6, and the findings for the other 4 sub-categories (Figure 1) are shown in Table 7.

3.3.1. Knowledge of instructional strategies and methods for teaching science, and ability to apply

Table 6 compares the primary school teachers' teaching strategies, methods, and techniques they stated in the interviews and observed that they used in science teaching. The competencies of the teachers were determined according to their knowledge of methods and techniques, their choice of methods, techniques and materials related to the subjects, their teaching principles (principles such as suitability for purpose, suitability for the student) information and their consideration of the principles. Gaye was the only teacher who prepared the activity sheets herself, and she also included different activities, but it was also noted that she was insufficient in using technology during the course.

> Gaye: "Now you are all flowers. Your head is the flower part, your arms are the leaves, and your feet are the roots. When you hear sunlight on the right, you will turn to the right together with the leaves, and when you hear left, you will move to the left. When you hear that water is on the left, you will move to the left, ..."(The students applauded the winner.) (Course Observation #2, 3:38-6:12)

Mert also used many traditional and contemporary methods (Table 6.). In Mert's lesson, who also used the drama method, the students' participation was high, and they were comfortable and enthusiastic in the course.

> S: “I am a giraffe. My height is between 4.5,6 m. It is spotted. (The student read the poem by wearing the animal mask on his face.) I am a giraffe. I'm a land creature, I live in Africa, I'm the tallest land animal.”
> Mert: “Let's applaud your friends.” (Course Observation #2, 34:35-37:16)

It has been determined that Sude, who frequently mentioned the importance of questioning and research, is insufficient in the variety of teaching methods.

> Sude: “Children will definitely use what they have learned in class in their lives. Maybe they will question everything. Why do we learn about living organisms? Why are we different from one another?... Why do insects respire differently?" (Interview #3, 632-637)

3.3.2. Knowledge of science education tools and materials

As seen in Table 7, teachers' views on which tools and materials can be used in science lessons focus on the internet, textbook, microscope, and supplementary resources. Sude also stated that everything in the living space can be used in science courses. Gaye, on the other hand, stated that the subjects in the science course are intertwined with the environment and therefore the environment is the most important tool. Apart from this, Arda, Gaye, and Mert stated that they used the microscope. Sude, Mert, and Arda existed all were using the projection device during teaching.

3.3.3. Level and skill of using technology in teaching

The course observations revealed that Sude, Mert, and Arda easily used the computer, projector and microscope in their classrooms and benefited from the internet.

> Mert: ".. almost everywhere I go, I try to shoot something on my camera, different things. ..I bring it and show it to my children. I even film the arrival of a stork and show it ..” (Interview #1, 269-272)

In this context, it was observed that Arda benefited from the education site he was a member of during the teaching process. Sude, on the other hand, mentioned how the use of technology facilitates the work of teachers and the positive aspects of supporting education with visuals.

Table 6
Results of Knowledge of Instructional Strategies Subcategory 1

	Arda	*Gaye*	*Mert*	*Sude*
Teacher Interviews	Learning by Doing-Living Student-centred Deduction Induction Question-answer Research-Exploration Trip-observation Experiment Project	Group Study Individual Study Experiment Observation Research-Exploration Question-answer Brainstorming Discussion	Group Study Interdisciplinary association Drama Research Straight Expression Slide presentation Web-assisted teaching Teaching with games	Narrative Expression Group Study Experiment Question-answer Research
Course Observations	Straight Expression Question-answer Observation Concretization Experiment (in class.)	Narrative Expression Brainstorming Illustration Observation Concretization Activity sheets Teaching with games Experiment (in class.)	Straight Expression Question-answer Group study Slide presentation Demonstration Research-Exploration Performance task Observation Drama Experiment (in lab.)	Straight Expression Question-answer Experiment (in class.)
General evaluation	Partially Sufficient	Partially Sufficient	Quite Sufficient	Insufficient

Table 7
Results of Knowledge of Instructional Strategies Subcategories 2, 3, 4, 5

KIS Sub. Categor.	*Data Collect. Tool*	*Arda*	*Gaye*	*Mert*	*Sude*
2.	*Interview*	Textbook Microscope Internet Computer Supplementary resource Projection device Lamp Picture Notebook Paper Seed Glass pipes	Textbook Microscope Internet Laboratory Equip. Test books Battery Cotton Crayons Plants Brochures/ posters Rainwater Beans, chickpeas Everything around	Textbook Microscope Internet Computer Test books Projection device Magnifying glass Compass Earth globe model Solar system model Wire, cable Skeleton model Glass funnels Animal organs	Textbook Laboratory Equip. Internet CDs Supplementary resource Projection device Glass Classroom environment Toy Student bag Everything around
3.	*Observation*	Sufficient-High Computer, Projection device Microscope Internet Educational sites	Insufficient-Low Microscope	Sufficient-High Computer, Projection device Microscope Internet	Sufficient-Moderate Computer, Projection device Microscope Internet
4.	*Interview*	Sufficient	Insufficient	Sufficient	Partially Sufficient
	Observation	Sufficient-High	Insufficient-Low	Sufficient-High	Insufficient-Low
5.	*Interview*	Schoolyard Educational trip	Schoolyard	Schoolyard Invite Professional groups	Schoolyard Invite Professional groups
	Observation	No out-of-class	No out-of-class	No out-of-class	No out-of-class

> Sude: "..I said make paper at home. The assignment came on a flash drive. I was surprised. ..this kid did something that I never thought of. He recorded it with his mobile phone. He also included the family. So I didn't make anyone do this. It's like saying I did it." (Interview #3, 555-567)

However, although Gaye stated that she was a member of educational sites and benefited from technology as much as possible, it was observed that even though she had internet and a computer in her classroom, she did not benefit from any technological tools other than microscopes in her teaching process.

3.3.4. Level and skill of using models, graphics, pictures, etc. in teaching

With the help of projection, Mert and Arda enriched the teaching process with animated presentations, related figures, diagrams and graphics by projecting visuals such as pictures of living and non-living objects, pictures of various habitats, microscope shapes, concept maps, and microscopic live images on the board. Sude, however, only drew attention to the visuals in the textbook. Gaye noted the subject headings on the board, and after stating that the excretory organs resembled two small beans, she only drew a kidney shape on the board at a simple level and did not benefit from the relevant visuals such as models, pictures, and shapes.

3.3.5. Utilization of out-of-class environments and resources in teaching

Arda stated that he started the EKLC unit in the schoolyard and that he motivated his students by attracting their attention, that he asked families to participate in the learning process, and that they also made educational trips. Gaye emphasized the importance of the environment, school, and family triangle and emphasized that they were planting trees in the schoolyard. Mert, who used the laboratory environment for extracurricular research, also made use of the toys and pets of the students in the activities held in his classroom. However, the course observations showed that the participants were not benefiting enough from the environment in teaching, and they gave little place to educational trips and observations.

> Mert: “Now, those who brought living beings and those who brought their non-living form come to the front.”. (Living and non-living were compared according to their characteristics such as movement and nutrition.) (Course Observation #2, 31:17-33:22)

3.4. Primary School Teachers' KAS Results

The measurement and evaluation processes of primary school teachers in science education are among the indicators of their PCK status. The results of the primary school teachers in 3 subcategories of KAS are presented in Table 8 in the order in the PCK model of the research (Figure 1).

Table 8

Primary school teachers' competencies in KAS subcategories

KAS Sub. Categ.	*Data Collect. Tool*	*Arda*	*Gaye*	*Mert*	*Sude*
1	Interview	Multiple-choice test Gap filling True-False	Open-ended exam	Open-ended exam	Open-ended exam
	Observation	Multiple-choice test Matching True-False Gap filling	Multiple-choice test Matching Comparison Gap filling Observation notes	Multiple-choice test Experiment form	Multiple-choice test Matching True-False Gap filling
2	Interview	Insufficient	Insufficient	Insufficient	Insufficient
	Observation	Partially Sufficient	Partially Sufficient	Partially Sufficient	Partially Sufficient
3	Observation	Insufficient	Insufficient	Insufficient	Insufficient

3.4.1. Methods used to measure and evaluate science learning

As seen in Table 8, in the 1st subcategory regarding the types of assessment and evaluation methods and techniques applied by the teachers, all teachers except Arda stated that they preferred open-ended written exams, yet course observations revealed that they were in fact using other classical methods and only Arda was actually applying the methods he stated. Unlike other teachers, Mert asked his students to write their observations with figures and fill in the experiment form after the experiments he conducted in the laboratory:

> Mert: "Yes, we will note the shapes you have seen in the experiments we have done in our notebooks. And we have examples of plans. We will fill in those plans. (experimental plan)" (by walking around the class) (Course Observation #5, 34:32-35:22)

Gaye, who made use of the student workbook in science teaching, used techniques such as matching, comparison, and gap-filling from the worksheet she prepared for repeating what was learned rather than for evaluation. She also reserved blank spaces in the worksheet for observation notes on germination.

3.4.2. Knowledge of Alternative Assessment Techniques (AAT)

Arda and Mert, who stated that they did not know or have no knowledge about AAT when asked directly, mentioned AAT unconsciously under other questions, and it was observed that they sometimes included such practices in the course. It was determined that they did not know AAT as a term, but applied techniques such as *performance evaluation, project, portfolio, and activity evaluation* in their teaching processes.

> Mert: "Now, those who brought live animals and their non-living forms come to the board. (The entities were compared according to their characteristics such as movement and nutrition.) Look, I hear a voice. Do you hear?"
> Students: "Bird!!! Yes!!!"
> Mert: "…Yes. We will put them in our portfolio." (Course Observation #2, 31:17-33:22)

> Arda: "There is that performance in the children's classroom, there are projects after that. There are activities.. Which students do their homework… When I enter their grades online, I evaluate the child's performance in the class." (Interview #3, 757- 760).. "There are activity files and portfolios." (Interview #3, 894)

In the interview, when asked directly about AAT, Gaye emphasized concept maps, self-assessment, and peer assessment, Sude described mind map and word association.

> Sude: "You give some data. The arrow sign originating from this data, for example, we said science. What do you know? Write 5 pieces of information about science around the arrows. (Mind map) (Interview #3, 648-652)

3.4.3. Importance given to measurement results

As shown in subcategory 3 in Table 8, all of the teachers were insufficient in using and giving importance to the measurement results appropriately. Course observations revealed that Arda solved the questions on an education site on the internet by projection at the end of the unit, followed the answers of the students carefully, and immediately corrected the wrong answers (Course Observation #5, 3:11,6- 35:48,2). Sude distributed test sheets to the students and solved the questions with them at the end of the time given for the solution, and warned the students who gave wrong answers to be careful (Course Observation #4, 33:48, 1- 37:45,0). Gaye said "*If learning is lacking, I will need to repeat it* (Interview #3, 535- 537)" during the interview, but none of the three teachers included complementary activities such as repeating the teaching on subjects that were not understood or revising the course by applying new methods and techniques. Indeed, Mert asked students to determine their correct and incorrect answers by only giving the answer key after the multiple-choice test.

3.5. Primary School Teachers' PK Results

PK includes general aspects of the teacher's knowledge of teaching, that is, “not subject-specific, such as learning theory, teaching principles, and classroom discipline” (Abell, 2007, p.1108). In this sense, the results obtained in the PK subcategories in the research model in Figure 1 are given in Table 9, and detailed explanations and citations are also presented under the headings related to the subcategories.

3.5.1. Self-efficacy views of science teaching

Most teachers are partially self-confident about their science teaching competencies. Arda, Gaye, and Sude stated that they had some deficiencies but still considered themselves sufficient in science teaching. Mert, who wanted to emphasize the richness and changing nature of scientific subjects, stated that the world and the environment we live in are constantly changing as well as people and their needs, so he does not consider himself sufficient in science teaching.

3.5.2. An understanding of the ideal teacher and teaching competencies

The characteristics stated by teachers who have different views and many concepts about ideal teacher characteristics were classified according to the PCK categories of the present research (Table 9, Subcategory 2.). Arda described the characteristics of the ideal science teacher by giving examples of PK categories such as loving children, researching, being observant, being honest, using body language well, being careful in time management, trying the experiments to be done before, as well as examples of KIS categories such as motivating students with different methods and techniques at the beginning of the course and having them do research.

> Arda: “No matter who, science teacher,... .etc. first, should love children. The child should be able to express his thoughts easily... When on the board, the child should not hesitate '' (Interview #1, 111-116)

Gaye thought that teachers should have some features in the PK categories such as positive communication, motivation to the lesson, getting to know the student, self-development, using appropriate gestures, mimics and tone of voice, and following science; in SMK skills such as good knowledge level; in KAS categories such as controlling student work and giving feedback, and in KIS categories such as the necessity of knowing teaching techniques and using technology.

> Gaye: ''First of all, should follow the developments in the field of science. Because children seem to be one step ahead of us.. a subject that you have never noticed, that you do not know can catch their eye.. Teachers should follow the innovations.'' (Interview #1, 95-105)

Mert expressed PK skills such as positive communication, motivating for the course, guiding, arranging the teaching environment, SMK skills such as good knowledge level, KIS skills such as the teacher's attention to in-class activities for encouraging them to become a scientist during science teaching. Sude, mostly mentioned PK competencies, stating that the ideal science teacher should develop herself, read the newspaper, watch documentaries and follow technology, love the student, communicate positively, appropriate facial expressions, and tone of voice. In accordance with the SMK and KIS categories, Sude stated that a science teacher who keeps up with the time and age should be fully equipped and support the students.

3.5.3. Classroom management

Classroom management skills of teachers were examined not only in terms of noise management, but also under 7 headings as shared in PK subcategory 3 in Table 9, and certain results and quotations from many results were shared in the same order.

a) Organizing the teaching environment. First of all, the class sizes of the teachers participating in the research were examined and it was determined that there were 25-35 students in Sude, Arda, and Mert's classes and 10-15 students in Gaye's class. Teachers Arda and Sude preferred the

Table 9
Primary school teachers' competencies in PK subcategories

PK Sub	Arda		Gaye		Mert		Sude	
Categ.	*Interview*	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*	*Interview*	*Observation*
1.	Partly High	-	Partly High	-	Low	-	Partly High	-
2.	KIS, PK	-	SMK, CKS, KIS, KAS, PK	-	SMK, KIS, PK	-	SMK KIS, PK	-
3.								
a.	-	Suitable	-	Suitable	-	Suitable	-	Suitable
b.	-	Partially-Suffi.	-	Partially-Suffi.	-	Partially Suffi.	-	Partially Suffi.
c.	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
d.	Positive	Positive	Positive	Positive	Positive	Positive	Positive	Positive
e.	-	Sufficient/ Partially Suffi.	-	Sufficient/ Sufficient	-	Sufficient/ Sufficient	-	Sufficient/ Sufficient
f.	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Quite Sufficient	Sufficient	Sufficient
g.	Open communic.	Partially suitable	Open communic.	Partially suitable	Open communic.	Partially suitable	Cautious communic.	Partially suitable

classical layout, where two people sit in a row, Gaye preferred the U layout, and Mert preferred the U layout in the laboratory and cluster sitting in the science classroom. Primary school teachers are also responsible for the general condition of their classrooms. In this sense, all teachers' classes were suitable in terms of heat, light, cleanliness, and seating arrangements.

b) Time management. All of the primary school teachers were structuring and implementing their teaching in accordance with the teacher's guidebooks and the annual plans that were divided into units of science acquisitions determined in the guidebooks with the distribution of the teaching period into months and weeks. However, it was determined that the teachers did not pay attention to the start and end times of the course. On the other hand, it was observed that, with respect to the behaviour regulations concerning classroom management and time management, all the teachers tried to make the students adopt the rule of raising their hands.

c) Knowledge of learners and their characteristics. This sub-dimension tries to determine the teachers' level of knowing their students, level of awareness of their students, and their sensitivity to their problems. It was observed that each of the participants knew their students and addressed them mostly by their names, and they were aware of their students' general living conditions and family structures. Moreover, Sude and Gaye were very attentive and careful toward inclusive education, considering their behaviour toward students with special situations in their classes. During the course, Sude touched her sick student, whom she mentioned to be sick frequently during the interview, with compassion and asked if she was with a sad expression. Arda also knew his students, supported their social relations and was sensitive to their problems.

> S.: “My mother had surgery. The operating room is very cold. So that germs don't breed.”
> Arda: “Oh look, the simplest example. Your friend's mother had surgery. He says it's cold there. Did you say get well soon to İbrahim because his mother had an operation?” (Course Observation #3, 14:02-15:26)

d) Communication skill. As seen in Table 9, the communication skills of all teachers were found to be sufficient and positive. It was observed that Gaye often laughed in her class, joked with her students, communicated by touching, listened carefully, and tried not to hurt students who gave wrong answers.

> (When the laughter continued after the student compared the germinated plant to an egg, the teacher said the following so as not to offend the student:)
> Gaye: You said it so everyone would laugh, right?
> S.: (Thinking a bit) No. (The whole class and the teacher laughed.) (Course Observation #5,13:34-14:05)

Arda and Gaye were of the same opinion that teachers should love children, listen to all students, and not offend them. Arda also stated that his students felt close and could easily share their feelings with him.

> Arda: “I have a lot of students who call me dad. One even wrote under today's exam, saying; 'I love you very much, my teacher'.." (Interview #2, 390-395)

Sude, who was observed to joke with her students, stated that she communicated with her students by touching them and that teachers should be given in-service training on communication from time to time. Mert also stated that he treats his students like a father with mutual respect. During his teaching, it was observed that Mert thanked his students, reinforced their positive behaviours, and tried to encourage them to the course.

e) Body language and diction skills in the teaching process. It was noted that most of the teachers paid attention to pronouncing words correctly and using tones appropriately, but Arda occasionally included local discourses during communication. Arda also used body language frequently while presenting a representative case. Gaye, Sude and Mert were careful about pronouncing the words correctly during their communication, and even corrected the students' mispronunciations.

> Sude: "Your diction, you should speak each word distinctly, but your tone should rise and fall from time to time, to attract the student's motivation." (Interview #2, 308- 323)
>
> Sude: (She turned to the mainstreaming student.) "Ayşenur, do living things feed? Do living things eat food? (By doing the eating gestures and getting closer to the student). " (Course Observation #1, 9:43,7- 10:22,6)

f) Developing a positive attitude towards science course. Primary school teachers' ability to develop positive attitudes towards science was at a sufficient level. It was noted that Arda carefully observes his students and tries to make them talk and active. In addition, Arda, Gaye and Mert encouraged their students to think and research on existing phenomena or events. Gaye included various games in the science course to increase students' interest in the course, and tried to make them eager for science by making use of the narrative expression/representative case method at the beginning of the class.

> Gaye: "There was a man. Every day he would take two buckets on his shoulders and go to the water. He carried water to his house. But, one of the buckets was punctured. He hung the one with hole in the same direction every day. After a while he saw… What do you think might have happened?" (Course Observation #2, 0:00-1:16)

It was noted that Sude tried to develop a positive perspective towards science and the environment. In Mert's class, the activities were effective and numerous, the students were active and motivated to research, and their expression skills were at the desired level.

> Mert: "..more inventions will be made.. our children should be warned and motivated about the development of science.. I think the science course is very suitable for this." (Interview #1, 78-84)

g) Reactions to critical situations and undesirable behaviours. Teachers' possible reactions to critical situations were tried to be determined with the question "What do you do when your students ask a question you don't know the answer to?". Gaye, Arda and Mert stated that they would clearly state that they did not know what the answer to the question asked was and would encourage them to research. Also, unlike the other participants, Arda said, "…I would say I don't know. I would tell them to research. I would say I should ask this to our science teacher.". Sude, on the other hand, thought that this could cause distrust towards the teacher;

> Sude: "..we came across such a question when the bell was about to ring. I was in such a shock. We said, let's answer this question tomorrow. If the question had come at the beginning of the course, I would have stumbled..." (Interview #2, 352-387)

Regarding reaction to undesirable behaviours, while all of the teachers showed reactions such as warning by voice, raising their voice, using body language and scolding, Gaye was the only person who warned them by getting close the student.

4. Discussion and Conclusion

4.1. Primary school teachers' subject matter knowledge of science

Primary school teachers' SMKs related to the science subject chosen for the research were evaluated on the basis of both SMKT, which is a knowledge test, and 6 different SMK subcategories. Even though some of the options marked by the teachers in the SMKT, in which they had moderate success, were correct answers, it was determined that some of the explanations for these options were not based on scientific grounds. This reveals the importance of teachers not only having knowledge at the level of information or comprehension, but also having a high level of conceptualization for teaching. On the other hand, "S*cience substantive knowledge*" was found to be higher and teaching activities were more effective for teachers who scored higher on SMKT on the basis of germination issue. While secondary school teachers usually specialize in one discipline, primary school teachers' simultaneous specialization in several disciplines (Ball, & McDiarmid, 1990) may make it difficult for them to master the all subject. In addition, *science misconceptions and conceptual difficulties* were identified in subjects such as respiration, photosynthesis, and the names of laboratory materials in all teachers, except for the teacher whose explanations about the test options were generally correct. Many studies have highlighted similar science misconceptions (Demircioğlu et al., 2004; Kaptan & Korkmaz, 2001; Yavuz & Çelik, 2013)and lack of content knowledge (Hanuscin et al., 2018) of teachers. Primary school teachers' subject-based or examination method related different SMK levels can be attributed to the diversity and richness of science course subjects, as well as to differences in learning and teaching practices. It is seen that teachers can have different PCK forms at the same time, and beginner teachers do not even have field and subject orientations at first, but then all teachers acquire knowledge about content, goals, and students (Lee & Luft, 2008). It was determined that teachers had similar characteristics in the other 4 subcategories compared to the first 2 SMK subcategories. The teachers "*gave sufficient and suitable examples*" to their students mostly through representative cases in science subjects, and their aims are generally to be more explanatory, to concretize, to encourage students to think about situations, etc. The teachers were all quite successful in "*associating the subject with in-class and other courses*". These results can be explained by the fact that the primary school teachers generally teach all the subjects of the students in primary school and therefore they have a good command of the subjects and order of the other courses. One of the potential sources of SMK is teaching experience in classroom (Ball & McDiarmid, 1990). Again, it was determined that the teachers were sufficient in "*ask effective questions about the science subject*" and they used these questions for purposes such as drawing attention to science achievements, motivating students to the course, revealing preliminary information about the subject and encouraging them to research (Friedrischsen et al., 2009). It was also noted that teachers generally had no difficulty in "*answering student questions*", but the sufficiency of their answers varied from subject to subject. Hanuscin et al., (2018) also emphasizes that PCK, which primary school teachers can develop specifically for a particular science subject, cannot be generalized to other grade levels and subjects. In this case, no direct relationship was found between SMK and other PCK sub-elements (Henze et al., 2007; Mıhladız, 2010)

4.2. Primary school teachers' curriculum knowledge of science

The teacher's understanding of the importance of issues related curriculum as a whole, is an indicator of CKS (Park & Oliver, 2008). It was determined that all of the teachers had positive views on "*importance of science education*", the majority internalized the necessity of the course at a high level, but there were differences in the amount of importance they attached. Teachers mostly thought that the features of science subjects such as the relationship between the environment and life, the opportunity for students to know themselves, the wide subject area of the science, potential of visualization, permanence with experiments, suitability for research and learning by doing make it important and useful. Moreover, despite stating that they were trying to make their students feel the importance of science by encouraging their students to do research, solving problems, directing them to the cause of events, drawing attention to inventions, scientists and their characteristics, some of the primary school teachers did not apply most of these processes in their classes. Cohen and Yarden (2009) also emphasized that although teachers have positive beliefs about the curriculum, there are contradictions between real classroom practices. Besides, primary school teachers did not mentioned about the content of the program, what "*science education goals and objectives*" and "*learning domains of Science Education Program*" are, and how they will be implemented, these situtions also reflected in their teaching. These results are consistent some studies that regarding the lack of theoretical knowledge about Scientific process skills (Laçin Şimşek, 2010; Türkmen & Kandemir, 2011) and general curriculum knowledge deficiencies (Friedrichsen et al., 2009). In addition, the results of the research are completely similar to the results of Tekbıyık and Akdeniz (2008), which reported that teachers make an effort to implement the program, but encounter some problems because they do not know the program well enough. Course observation-based evaluation of the primary school teachers' *knowledge of subject-specific program outcomes* has shown that all of the teachers included various activities related to "microscopic living things" in their classrooms and they carried out appropriate experiments using a microscope, and in this context, they had sufficient knowledge about living things issue. However, each of the components requires subject-specific knowledge, the objectives and curriculum differ for individual courses (Kind, 2009). In this regard, it is found that half of the teachers had insufficient content knowledge and knowledge of learning outcomes about the conditions necessary for dormant organisms to show vitality.

4.3. Primary school teachers' knowledge of instructional strategies in science teaching

In the context of "*knowledge of instructional strategies and methods for teaching science, and ability to apply*", one of the KIS subcategories, besides the fact that the teachers could not give examples of the approach/theoretical strategies reflecting the vision of the program in the interviews, most of the teaching methods they stated were not encountered in the course observations. The course observations revealed that all of the teachers frequently used straight expression, question-answer, observation and experiment methods. Similarly, Yeşilyurt (2013) found that in addition to the methods mentioned above, discussion and demonstration were generally preferred by primary school teachers, while Koç and Bayraktar (2013) reported that the experimental method was generally preferred. In general, it has been determined that most of the primary school teachers prefer traditional teaching rather than contemporary methods and techniques (Friedrichsen et al., 2009; Van Driel et al., 1998; Yangın & Dindar, 2007). Also, most of the teachers had an average level of "*knowledge of science education tools and materials"*. Even knowledge of resources in science teaching affects the choice of instructional strategies, curriculum arrangements and the use of assessments (Lee & Luft, 2008). They gave examples of a few materials and tools, mostly based on technological tools and science experiments and activities in their general teaching. The finding of Tekin et al. (2012) that prospective primary school teachers do not recognize some laboratory materials is also valid for teachers. Indeed, it was also determined that the teachers used the names of materials such as slides and coverslips (lam and lamel in Turkish) interchangeably. It was also concluded that most of the teachers had difficulties in performing laboratory practices (Çepni et al., 2003). As a matter of fact, all of the teachers gave examples of environments and activities related to the external environment, such as the schoolyard, educational trips and inviting professional groups to school for "*utilization of out-of-class environments and resources in teaching*". Most of the teachers did not benefit from the external environment, different materials and these practices. All of the teachers had positive opinions about "*Level and skill of using technology in teaching*" and except for the teacher who had high science substantive knowledge, the others considered themselves sufficient. Again, consistent with their views, it was observed that all teachers, except this teacher, enriched their science teaching processes with the technological tools they used. In addition, it was found that male teachers had higher technology use skills (Aktepe, 2011; Demir et al., 2011; Yavuz & Coşkun, 2008) and "*Level and skill of using models, graphics, pictures and etc. in teaching*" than females.

4.4. Primary School Teachers' Knowledge of Assessment in Science

The majority of teachers stated that they preferred "open-ended exam questions" related the "*methods used to measure and evaluate science learning*". However, it was observed that all of the teachers applied the multiple-choice test, and the majority of them applied gap filling, matching and true-false questions, which are considered traditional assessment and evaluation techniques. Consistent with this research, Gelbal and Kelecioğlu (2007) concluded that teachers prefer traditional assessment methods in determining student achievement because they consider themselves more competent in these methods. In addition, it was determined that the majority of the teachers who used the observation method on germination issue, asked the students to express their observation results in writing, but did not use an observation or experiment form. Moreover, although most of the teachers did not have conceptual and functional "*knowledge of AAET*", they partially included some applications such as project assignment, performance task and student portfolio in their teaching processes (Duban & Küçükyılmaz, 2008; Gök & Şahin, 2009). Similar to the results of Güneş et al. (2010), it was observed that AAETs were used to ensure permanent knowledge through learning by doing, increase participation and draw attention to the course, rather than measurement and evaluation. But teachers stated that they use it for purposes such as measuring the comprehension of the subject, discovering students' interests, take responsibility in learning, and become capable of self-evaluation, as well as increasing their creativity. In this sense, teachers did not apply assessment as a way to help students monitor and evaluate their own learning (Friedrichsen et al., 2009). In the "*Importance given to measurement results*" subcategory of KAS, it was determined that teachers shared the measurement results obtained from the evaluation methods in science courses and rarely the solutions with the students, but they were insufficient in taking the results into account, evaluating students' results, correcting the deficiencies and mistakes by giving feedback or renewing the teaching. Besides, they did not use any rubrics due to their lack of knowledge about AAET. Consistent with the findings of the present study, Acar and Anıl (2009) also concluded that experienced primary school teachers do not have sufficient knowledge about rubrics for AAETs and they need an assessment specialist for rubric use.

4.5. Primary School Teachers' Pedagogical Knowledge

In the study, primary school teachers' PCKs were evaluated on the basis of many subcategories of PC. The "s*elf-efficacy perceptions on science teaching*" of the teachers, who stated that they may have deficiencies due to the nature of the science field, its rich content, and the variability of science, were found to be partially high. Although primary school teachers often lack self-confidence in teaching science, they try to teach as best they can (Appleton, 2003). But it is seen as a necessity for teachers to have high self-efficacy in order to be more successful in science education (Acar, 2012). In addition, considering that classroom teachers' understanding of "*the characteristics of an ideal science teacher and the competencies essential for teaching*" may be a reflection of their professional development and knowledge, their views were taken and classified based on the PCK model of the research. The characteristics that the teachers expressed most intensively were the competencies related to the KIS and PK categories and stated that teachers having a sufficient level of knowledge under the SMK category. On the other hand, statements that may concern the CKS and KAS categories were expressed in a few sentences by only one teacher. It has been revealed that teachers' PCK conceptualizations affect curriculum arrangements, the choice of instructional strategies, and the use of assessments (Lee & Luft, 2008), and their views on teaching competencies reflect their teaching processes.

"*Classroom management*", one of the PK categories, has also been examined in 7 sub-dimensions. It has been concluded that the primary school teachers' teaching the same students in many branches for a long time (this period is 4 years in Turkey) gave the teachers an advantage in "*knowledge of learners and their characteristics*", "*communication skill*" with students and their parents, "*Developing a positive attitude towards science course*" for students, "*body language and diction skills in the teaching process*", "*organizing the teaching environment*" and "*reactions to critical situations*" and that they were generally competent and behaved appropriately. In the context of PK, it is clear that the contribution of teaching experience and subject familiarity to PCK (Friedrichsen et al., 2009; Van Driel et al., 1998). In this context, all of the teachers frequently used the question-answer method to make students who are not interested in the lesson, distracted, and never speak to participate and some teachers occasionally preferred different teaching methods such as games, storytelling, research, presentation, and experiment to develop positive attitudes. However, the teachers were not successful in "*time management*", coming to the class on time, and finishing the course with the course end bell, and they did not care enough about the course durations. This time, the multi-course teaching situation caused them to be flexible about the use of time. Also teachers showed "*reactions to undesirable behaviours*" such as warning the students by voice, raising their voices, using body language, and scolding, but they did not use the ignoring reaction at all.

5. Implications and Future Research

It has not been possible to reach definitive conclusions about the competencies of primary school teachers in PCK and its subcategories in the context of science teaching. In general, except for PK, in addition to the level differences between teachers, a teacher's competencies and knowledge/skill levels can vary from subject to subject or situation to situation within the same category. PCK is a complex concept as it emerges from various human interactions in different contexts (Fernandez 2014). Besides, the rich subject content of science education can also be considered a factor. Some of the factors affecting teaching are explicit, such as the curriculum, while others are implicit, such as the teacher's intentions and beliefs about science teaching and learning (Shing et al., 2015). PCK is an internal structure and is even implicit in most applications (Cohen & Yarden, 2009). According to the results of the research, it was concluded that instead of making standard generalizations about teachers' PCK, explaining the situation over sub-categories and making comparisons on the basis of teacher competencies can guide our PCK understanding. In this sense, the PCK category, in which experienced primary school teachers are the best compared to other categories, is PK, which is consistent between teachers and within each teacher's own levels. In this regard, it is thought that their branches and experiences give them an advantage (Canbazoğlu, 2008) and being together with the same students for a long time of 4 years increases the knowledge/skill levels of their PK subcategories. Nevertheless, it has been concluded that there are some deficiencies in the integration of the experience and knowledge they have gained into the teaching processes.

The weakest PCK categories of primary school teachers were KAS and CKS, respectively, which is consistent with the fact that teachers did not mention KAS and CKS competencies in their perceptions of ideal teacher competencies. In general, the teachers did not follow the National Science Curriculum or teacher's guides first-hand but conducted their lessons through textbooks and supplementary books. Therefore, although all teachers mention the constructivist theory, which is the fundamental approach on which the program is based, and some contemporary acquisitions, they do not have sufficient knowledge about the lerning outcomes, main objectives and content of the program. Of course, this situation also leads to inadequacies in using appropriate contemporary learning-teaching processes, strategies, alternative assessment methods, and rubrics. As expected, teachers' KAS and CKS also significantly affect KIS. In this sense, learning teachers' individual goals, intentions and feelings regarding science teaching may aid in drawing a more accurate roadmap (Dpaepe et al., 2013; Park & Oliver, 2008). In addition, teacher professional development trainings should be programmed, and exemplary contemporary teaching methods and alternative measurement and evaluation techniques specific to science should be practiced with teachers.

The competencies of teachers regarding SMK, which is one of the basic elements of PCK, differed according to science subjects, teaching practices, and the type of SMK assessment methods applied to them. Nevertheless, it has been observed that experienced primary school teachers' good PKs provide an advantage in overcoming SMK deficiencies and difficulties in some teaching processes. However, especially primary school teachers' misconceptions or their preferences for teaching science concepts that they have difficulty with may lead to a rotten ground for students' fundamental science education. In this sense, more detailed studies should be carried out to determine the SMK status and resources of teachers. Also in this context, the PCK model of the research, which provides comprehensive results, can be recommended as an explanatory guide for other studies.

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