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Exploring Preschool Teachers' Pedagogical Content Knowledge: The Effect of Professional Experience

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ABSTRACT This study aimed to explore the pedagogical content knowledge (PCK) of preschool teachers. This multiple case study was conducted with the participation of two preschool teachers. In this way, two preschool teachers' PCK about science teaching was examined, and it was attempted to determine the underlying causes of their pedagogical conceptualizations about any subject. Therefore, the participants were asked to create a lesson plan specific to the subject matter they selected, answer the interview questions about PCK, and implement the lesson plan they created. While the participants' responses to the lesson plan and PCK interview questions were analyzed by inductive content analysis based on the constant comparative method, classroom observations were evaluated with an analytical evaluation rubric. Furthermore, PCK maps showing the interaction between the subject-specific and unique PCK components of preschool teachers were created. Results revealed that teachers did not have sufficient knowledge about science teaching and that their PCK tended to change according to professional experience. It was determined that experienced teachers had more teacher-centered orientations than less experienced teachers with more student-centered orientations. Moreover, it was observed that professional experience increased the relationship between the PCK components.

Keywords Pedagogical Content Knowledge, Preschool Teachers, Early Science Teaching, Professional Experience

1. INTRODUCTION

One of the most vital themes in the national science standards is that all children can learn science, and all children have the opportunity to be scientifically literate (National Research Council [NRC], 2013; MoNE, 2013). Children need to make sense of what is going on in their environment from the moment they are born, and consequently, they develop some simple scientific skills, which constitutes the first science experiences of their lives (Furman, Luzuriaga, Taylor, Podestá, & Jarvis, 2019). Preschool education provides excellent opportunities to support children's curiosity, and effective science teaching in early education may lay the foundations of rigorous thinking and understanding about the nature of science. To achieve all of them, the importance of preschool science teaching should be well understood, and it should be aimed to provide children with the acquisition of basic science knowledge and skills (Cowie & Otrel-Cass, 2011).

Science education provided at an early age enables children to recognize the events in their environment and nature, perceive the relationships, make observations, interpret the knowledge, and acquire scientific process skills (Ravanis, 2017). Furthermore, children start to acquire environmental awareness and take charge of plants or animals such as nutrition and cleaning by obtaining the necessary knowledge to protect the environment. They develop a sense of responsibility by performing these tasks (Kurniah, Andreswari, & Kusumah, 2019). Therefore, science education in early childhood supports all areas of development of children. A research-based approach provides children with opportunities to make sense of the world and environment and satisfy their curiosity and learn scientific processes (Dejonckheere, Wit, Keere, & Vervaet, 2016). It supports them to gain the necessary knowledge in daily life and provides them with the ability to solve universal problems. Therefore, crucial importance should be given to science education in early childhood, and it should be integrated into the daily curriculum (Eliason & Jenkins, 2003). In this process, preschool teachers should

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create safe and risk-free study areas where children can make observations by doing research.

Furthermore, they should encourage children's active participation by giving them time to share their ideas to support their creativity and problem-solving skills (McLachlan, Fleer, & Edwards, 2018). With this aspect, preschool teachers play a crucial role in providing compelling science experiences and creating environments where children can perform these science experiences. Andersson and Gullberg (2014), who suggested that it would not be enough alone for preschool teachers to give children correct answers about any science subject, determined four skills that can be developed and used by preschool teachers:

- Paying attention to and using children's previous experiences,
- Capturing unexpected things that happen at the moment they occur,
- Asking questions that challenge the children and that stimulate further investigation,
- Listening to the children and their explanations.

Preschool teachers' levels of knowledge, views, attitudes, and self-efficacy about science subjects are significant predictors for a qualified science teaching (Saçkes, 2014). Furthermore, preschool teachers' limited pedagogical conceptualizations for science teaching will also affect their teaching quality (Neuman & Danielson, 2020). Therefore, it is necessary to explore preschool teachers' aspects representing their professional knowledge about science teaching in-depth. In this study, preschool teachers' pedagogical conceptualizations while structuring and implementing a science subject were examined.

1.1 The Role of Teacher in Early Childhood Science Education

Teachers play a crucial role in developing scientific thinking from early childhood and their positive attitudes towards science courses during elementary school years (Thulin & Redfors, 2017). The integration of the diversity of opportunities provided with teachers with different methods with positive attitudes and behaviors during science activities directs children to research, investigation, and examination, which are the foundations of scientific thinking. Therefore, it is necessary for preschool teachers to offer different options during science activities and to include children in the discussion processes related to science events (Bustamante, White, & Greenfield, 2018). Furthermore, preschool teachers should include science concepts in play-based activities integrated with the curriculum's achievements (Gerde, Pierce, Lee, & Van Egeren, 2018). Therefore, preschool teachers should develop more creative and original pedagogical strategies from primary or secondary school context-specific to science teaching (Blömeke, Jenßen, Grassmann, Dunekacke, & Wedekind, 2017). Previous results indicated that preschool teachers' science-specific knowledge was relatively low compared to science-specific knowledge of primary or secondary school teachers (Garbett, 2003). Andersson and Gullberg (2014), who conducted action research with preschool and primary school teachers' participation, problematized the objective of preschool science education and the competencies needed by preschool teachers to carry out science activities in the classroom. The researchers determined that preschool teachers failed to support children's conceptual understanding in science activities carried out with them, indicating that preschool teachers are inadequate in adapting science subjects to the preschool education context (Kallery & Psillos, 2001; Tu, 2006). However, Andersson and Gullberg (2014) suggested that preschool teachers needed more than just subject matter knowledge. Therefore, the factors affecting preschool teachers' pedagogical conceptualizations about science teaching should be evaluated from multi-perspectives.

1.2 Pedagogical Content Knowledge

Teacher knowledge is one of the most critical factors affecting teachers' classroom behaviors and their students' success (Shulman, 1987). Grossman (1990) collected the types of knowledge that the teacher should have to perform effective teaching under four titles: subject matter knowledge, general pedagogical knowledge, pedagogical content knowledge, and context knowledge. Accordingly, the most important qualifier of effective teaching is Pedagogical Content Knowledge (PCK). According to Loughran, Mulhall, & Berry (2008), PCK, which teachers develop and are a teacher-specific quality, is the subject-specific type of knowledge they have developed through time experiences. Furthermore, PCK is based on a mix of an understanding of the content that allows students to understand any subject and teacher pedagogy better. PCK is subject matter-specific, title-specific, teacher-specific, and content-specific (Kind, 2009). Magnusson, Krajcik, & Borko (1999), who contextualized the PCK based on science teaching, suggested that a teacher should have the following components for qualified science teaching:

- Orientations to teaching science (OTS): OTS reflects teachers' perspectives on science teaching.
- Knowledge about students' understanding of science (KSU): KSU includes students' concepts on specific topics, learning difficulties, motivation, and diversity of talent, learning style, the field of interest, level of development, and knowledge of needs.
- Knowledge of science curriculum (KSC): KSC represents the knowledge about the curriculum and curriculum materials.
- Knowledge of instructional strategies for teaching science (KISR): KISR indicates how the teacher benefits from instructional strategies and representation.

- Knowledge of science learning assessment (KAS): KAS represents the knowledge about the methods to evaluate students' content learning.

A teacher has specific insights and knowledge about the components of PCK before performing teaching and aims to use these knowledge structures during teaching within the framework of his/her plan. However, these knowledge structures and components undergo specific changes after teaching, which is his/her interactions with the students during teaching. These interactions lead to the emergence of teacher efficacy, which is a new affective component of PCK (Park & Oliver, 2008).

In the literature, it is observed that PCK, which is structured as an implicit form of teachers' professional knowledge, was generally conceptualized specifically for science teacher education (e.g., Loughran et al., 2008; Nilsson & Vikström, 2015). Furthermore, these studies were generally conducted with science teachers' participation or preservice teachers (e.g., Nilsson, 2013; Luft & Zhang, 2014). However, little is known about preschool teachers' pedagogical conceptualizations about science teaching and their professional knowledge level and structure. The studies indicate that qualified teaching support could encourage young children to learn (e.g., McLean, Jones, & Schaper, 2015; Larimore, 2020). However, it was reported that preschool teachers resisted while including science subjects in their teaching (Gerde et al., 2018). It was stated that this resistance was generally caused by the lack of material (Greenfield et al., 2009), limited understanding of science (Kallery & Psillos, 2001), and the lack of self-efficacy (Leon, 2014). Andersson and Gullberg (2014) argued that preschool teachers should have PCK, which is a characteristic that would go beyond their subject matter knowledge in order to perform an effective science teaching. For this purpose, preschool teachers should have extensive repertoires on play-based pedagogical strategies and children's cognition. Therefore, the way preschool teachers reflect their concepts for the subject matter to classroom practices is related to their PCK (De Jong, 2003). Furthermore, the ability to recognize domain-specific content in everyday situations can also be considered a component of preschool teachers' PCK (McCray & Chen, 2012). Accordingly, preschool teachers can improve their PCK by applying scientific activities in teacher education and in-service courses.

Abell (2008) criticized the use of similar samples (e.g., science teachers) in the studies on the development of PCK and emphasized that different samples (inexperienced – experienced teachers, etc.) should be compared within the same study. However, very few studies evaluate preschool teachers' science-specific conceptualizations based on their professional knowledge (e.g., Andersson & Gullberg, 2014; Furman et al., 2019). Therefore, following the recommendation of Abell (2008), the primary aim of this study was to explore preschool teachers' PCK about science teaching. The secondary aim was to determine how professional experience changed the structure of PCK.

2. METHOD

The multiple case study approach was used in this research conducted to explore preschool teachers' PCK about science teaching. The case examined in this study was to describe the PCK of preschool teachers continuing their postgraduate education about science teaching and to find the underlying causes of their pedagogical conceptualizations about any subject. For this purpose, data were collected from two teachers with different professional experiences through lesson plans, interviews, and observations. The holistic multiple case study was used because the data collected from all these sources were compared according to professional experience (Yin, 2017). This method includes comparing many situations to explain any case and provide insight into that case (Creswell & Poth, 2007). In the holistic multiple-case design, all cases are discussed as a whole within themselves and then compared. It was considered to reveal certain previously unknown situations related to PCK structures for preschool science teaching with such a study.

2.1 Participants

The participants were selected by the criterion sampling method, one of the purposeful sampling methods (Leedy & Ormrod, 2001). The criteria were that participants continued their postgraduate education, had different professional experiences, and worked in public kindergartens. Different names were used to keep the identity of the participants confidential (Patton, 2014). Detailed information about the participating teachers is presented below.

Barbara: Barbara is 23 years old. Barbara, who completed child development and education in high school, graduated from preschool teaching at a private university with a first. Currently, she is actively continuing her postgraduate education in the department of preschool teaching. During her undergraduate education, Barbara took a preschool science education course for only one semester concerning the study's subject. Barbara has two years of professional experience and is working in a public kindergarten. Barbara attended many seminars on preschool teaching during her student and professional life. However, there is no study on science education among these seminars. There is a total of 23 48-month-old children in the classroom of Barbara. There is a playing house center, Atatürk center, block center, science, and nature center where children can move quickly. Many different activities can be performed concerning her classroom's physical conditions.

Gwen: Gwen is 35 years old and the mother of three children. Gwen, who states that she preferred this profession because she loved children very much, is a teacher with ten years of experience. After completing her undergraduate education at a public university, she suspended her education for a while. She is currently continuing her postgraduate education in preschool teaching to improve herself in her field. Gwen was not involved in any science education study and did not attend in-service training or seminar during her student and teaching life. During her university education, she took a preschool science education course for only one semester. Therefore, she considered herself inadequate in science teaching. Gwen, who worked in three different institutions during her ten years of teaching, claimed that physical conditions prevented her, although she attached importance to science activities. There are 25 48-month-old children in the classroom of Gwen. For her classroom's physical conditions, it was observed that there was no place where children could easily play and perform their activities, and there were not adequate materials.

2.2 Data Collection

Three different data collection tools were used to describe the PCK of the participants in-depth. Data triangulation was achieved through these different data sources (Flick, 2018). These data collection tools are Lesson Construction Task (LCT), PCK Interview Protocol, and Classroom Observation. First, the participants were directed to LCT and PCK Interview Protocol. Then, teachers' science teaching in the classroom was observed. Each data collection tool was directed to teachers once. Before administering the interviews and LCTs, tools were externally audited by an expert specializing in preschool science teaching (Thomas & Magilvy, 2011). Finally, teachers' science teaching in the classroom was observed.

LCT

In this study, the (CoRe) methodology was used for preschool teachers to create lesson plans for any science subject (Loughran et al. 2008). In brief, a CoRe reflects an explicit science teaching content based on the recognition of 'big ideas' for any subject mapped against pedagogical demands. Therefore, CoRe was designed to reveal teachers' knowledge of teaching a particular science concept/subject. The questions included in a typical CoRe instrument were reorganized and integrated into interview questions by considering the five components in the PCK model of Magnusson et al. (1999) (Appendix-A). This form has been named LCT. Teachers who filled out the LCT statements were recorded with a voice recorder to obtain the data appropriately. The lesson plan's statements were adapted to the preschool context with the help of researchers who specialized in studies on PCK and early science teaching. The final version of the LCT consisted of six questions. It took approximately 30-40 minutes for each teacher to respond to the LCT. Preschool teachers used MoNE's (2013) preschool education curriculum while preparing LCT. For example, Barbara, who studies 48-month-old children, determined two learning outcomes 'children sort the events in order of the occurrence' and 'children explain the concepts of time'. She chose the formation of night and day topics to reach these learning outcomes. Also, she aimed to gain three scientific process skills as observing, classifying and predicting.

On the other hand, Gwen, who studies 48-month-old children, determined three learning outcomes' children pay attention to object/situation/event', 'children remember what they perceived', and 'children observe objects or entities'. She chose the formation of colors topic to reach these learning outcomes. Besides, she aimed to gain two scientific process skills as observing and predicting.

PCK Interview Questions

The interview protocol used to determine preschool teachers' PCKs for science teaching was presented to the participants in two parts. Part-I included two main questions and one probe question that help determine the teacher efficacy. Part-II consisted of questions representing the five-component PCK structure proposed by Magnusson et al. (1999). In these parts, each organized to represent a different PCK component, there were 22 questions, including five main questions and 17 probe questions (see Appendix-B). The order of five main questions according to the PCK components is as follows: OTS, KSU, KSC, KISR, KAS. The interviews lasted for a total of 50-60 minutes. All interviews were conducted using a voice recorder.

Classroom Observations

Classroom observations were conducted to obtain more perceptible and traceable knowledge about the PCKs of preschool teachers included in the study. This way, it aimed to understand better teachers' processes of realizing this knowledge and the context they taught (Park & Oliver, 2008; Andersson & Gullberg, 2014). Classroom observations were conducted using the observation protocol developed by Newton, Driver, and Osborne (1999). According to this protocol, classroom observations are generally conducted by following three necessary frameworks. These frameworks are activities involving children (PA), how they are grouped during the activities (PWG), and teacher-children interaction styles (P&TI) (see Appendix-C). Following the objectives stated here, what teachers and students did during the courses and at which moment (at one-minute time intervals) of the courses they did them were determined. Thus, both the practical form of the preschool teacher's PCK achieved through the interview protocol and how teachers acted in their classrooms while applying scientific activities were revealed. Before the teachings, teachers determined the learning outcomes suitable for early science teaching from the preschool education curriculum of the MoNE (2013), and they performed teaching according to them. Each teacher was observed once. Teaching observations were made by considering the teachers' time they were available. To do this, it has been negotiated with teachers, and the process is planned together. All of the learning outcomes were determined by the participating teachers. For example, Gwen conducted her instruction based on the 'children pay attention to object/situation/event', 'children remember what they perceived', and 'children observe objects or entities' learning outcome. Her central theme was colored. The instructions lasted for approximately 13-15 minutes. In this process, no other detail was mentioned to teachers. The researcher did not interfere with teaching during the observations. During the observations, these lessons were videotaped. In this way, field notes were reflected in the data analysis process.

2.3 Data Analysis

In this study, the content analysis approach was adopted to reveal the uncertain themes and specific themes, as Strauss and Corbin (1990) suggested. The inductive content analysis method analyzed the participants' responses to the LCT and PCK interview questions (Patton, 2002). In this process, the raw data obtained were first divided into meaningful parts and what each part meant conceptually was determined. Secondly, the common aspects between the codings obtained were found and turned into conceptual categories. The coding framework's focus was the five components of the PCK (OTS, KSU, KSC, KISR, KAs) and teacher efficacy for early science teaching. Thirdly, the codes and themes obtained were processed. Fourthly, the participants' responses to the LCT and PCK interview questions were comparatively analyzed in-depth under the study's aim by the Constant Comparative Method (Kolb, 2012), and the Coding Key containing analytical evaluation options was created. For example, for OTS, which was one of the components of PCK, if the teacher conceptualized her instructional goals as merely the transfer of knowledge on a specific topic, it was coded as teacher-centered. On the other hand, if the teacher made life-based conceptualizations instead of transferring knowledge, it was coded as child-centered.

After an in-depth analysis, to portray the interactions among teachers' PCK components in a quantitative sense, an enumerative approach and PCK mapping were employed (Park & Chen, 2012). Based on the assumption that there must be a connection between any two of the identified PCK components within the selected teaching episodes, it was counted the number of connections. It was defined the directions of these connections. Each connection within teaching episodes was given '1' to indicate its strength. Thus, it was created a unit system to quantify teachers' PCK's interconnections. After the enumeration process is completed, was drawn PCK Maps using the pentagon model as an analytic device. The interactions defined within the pentagon model were visualized through the PCK Mapping (Park & Chen, 2012).

The identified answers of a teacher (Gwen) during this process were sent to an expert researcher, and they were subjected to a separate analysis process. The expert independently analyzed these answers to draw a PCK map and to make the content analysis. After that, we came together and compared our maps and codes. The intercoder reliability percentage was achieved by comparing the analyses performed at different times and places (Kurasaki, 2000). This value, which was 89%, indicated that the analyses were proceeding reliably (Miles & Huberman, 1994). By coming together with the same expert again, the analyses' differences were discussed, and the remaining data were analyzed individually based on the criteria determined. Finally, all analyses were sent to the same expert, opinions were received for external control, and the process was completed. As a result, the final code list was created, and other analyzes were carried out based on this code list (Table 1).

The second step of data analysis consisted of analyses of classroom observations. In the analysis process performed by using the rubric developed by Newton et al. (1999), time sequences were made for each participant's instructional application according to PA, PWG, and P&TI. One more expert also participated in the analyses to ensure the reliability of evaluations. The rubric was first introduced to the relevant expertise, and a framework was created by performing theory-laden negotiations for each activity. Here, if the teacher gives direct information about the subject, it has been coded as listening under this PA category. This activity has also been coded under the P&TI category as a teacher explaining science. If the teachers have their students do group work, it has been coded as small group activity under the PWG category. The intercoder reliability rate for these analyses was 92%.

3. RESULTS

The results obtained by analyzing preschool teachers' responses to the LCT and PCK interview questions and their in-class teaching observations are presented in this section. First, the inductive content analysis results of teachers' answers to the LCT and PCK interview protocol questions are presented in Table 1 and then in the subtitles. Therefore, the teachers' views of Teacher Efficacy and PCK were interpreted through the themes and concepts obtained after the inductive content analysis. Then, two teachers' PCK maps were created and interpreted. Finally, the charts reflecting the time schedules of teachers' instructional practices were presented.

3.1 Teacher Efficacy

At the beginning of the process, the questions in LCT and PCK interview questions for science teaching in preschool education were asked to determine preschool science teaching's instructional competence. Accordingly, Barbara referred to utilizing the opportunities in teaching, recognizing changing situations, and child-centered processes. On the other hand, Gwen talked about the transfer of knowledge and teacher-centered processes.

Table 1 Themes and concepts about teacher efficacy and PCK

Categories	Themes and Concepts	
	Barbara	**Gwen**
Teacher Efficacy	*Utilizing the Opportunities in Teaching*	*Utilizing the Opportunities in Teaching*
	Classroom management	Classroom management
	Enriching teaching	
	Recognizing Changing Situations	*Teacher-Centered Processes*
	Being aware of the differences	Concept teaching
	Being able to distinguish the differences	Direct transfer (knowledge)
	Raising awareness	Expository Instruction
	Child-Centered Processes	*Teacher Efficacy*
	Associating knowledge with daily life	Lack of confidence
	Using information in different activities	Lack of in-service training
	Integrated activities	Curriculum-material inadequacy
	Teacher Efficacy	The misconception of strategy
	Lack of confidence	
	Lack of in-service training	
	Curriculum inadequacy	
OTS	*Structuring and Transferring Information*	*Structuring and Transferring Information*
	Access to information	Direct concept teaching
	Meaningful learning	Teacher-centered processes
	Associating with daily life	
	Child-centered processes	
	Using curriculum materials	
KSU	*Characteristic of the Subject Context*	*Characteristic of the Subject Context*
	Time concept	Primary and intermediate color
	Hour, second…	
	Instructional Diversity	*Cognitive Skills*
	Original activities	Concept knowledge
	Enrich-integrate teaching	Teacher-centered processes
	Child-centered processes	
	Developmental Features	
	Cognitive readiness	
	Psychomotor development	
KSC	*Orientations Based on Learning Outcome*	*Orientations Based on Learning Outcome*
	Suitable for age and developmental level	Integration with goals
	Insufficient focus of learning outcome	Presenting different perspectives
	Curriculum Competence	*Curriculum Competence*
	Lack of acquisition knowledge	Towards knowledge of learning outcome
	Inability to integrate learning outcome	Putting learning outcomes first
KISR	*Child-Centered Processes*	*Teacher-Centered Processes*
	Providing guidance in teaching	Teaching method by experiment
	Guiding the child to teaching	Rhetorical question and answer (teacher-student)
	Meaningful learning	Demonstration
	Strategy variety	
	Transition between activities (integration)	
	Motivational Strategies	*Teacher Efficacy*
	Increasing motivation	Classroom management
	Encouraging participation	Self-criticism in science teaching
		Autonomy in the context of the subject
KAs	*Alternative Assessment and Evaluation*	*Traditional Assessment and Evaluation*
	Observing affective features	Question and answer method
	Involving the child in the process	Knowledge-oriented assessment and evaluation
	Achievement-oriented assessment and evaluation	

Both teachers, who had different professional experiences, indicated that the importance was not attached to science teaching courses during their undergraduate and postgraduate education. Therefore, they considered themselves inadequate in science teaching. It was also determined that they referred to the curriculum's knowledge by indicating the curriculum's deficiencies.

Gwen: *I do not conduct science activities by myself in my classroom. Every week, a child presents a science activity that he/she conducts with his/her family at home to his/her friends. I want them to know which primary colors merge and which intermediate colors they create (Interview). I want them to know which colors will appear when they know the primary colors and the colors are mixed, they would make an effort to create intermediate colors in their activities, and they would keep the color combinations in mind and use them (LCT).*

Barbara: *First of all, I work with a crowded group. We have 20-21 people. Therefore, I implement my activity as a small group. I mean, according to the classroom size, the current situation of the children, or, depending on whether my previous activity was active or passive. I also structure my science activity according to my activity situation (Interview). I cannot say that I consider it exactly enough. I cannot say because sometimes I feel that I am inadequate in explaining some concepts. I try to reduce to what children can understand. However, sometimes I have a problem with the concepts, especially in explaining concepts (LCT).*

Gwen's conceptualizations, who gave similar responses to the LCT and PCK interview questions, indicated that she imposed task and responsibility to the child and made knowledge a purpose rather than a tool. On the other hand, it was determined that Barbara identified different strategies according to the changing situations in the classroom environment, cared about children being active in the teaching process, and ensured the acquisition of science education by enriching various activities related to the subject. However, she indicated that she sometimes had difficulty reducing some science concepts to a level that children could understand. She stated that she considered herself inadequate in teaching science during those times.

3.2 PCK Conceptualizations

PCK conceptualizations of teachers included in the study for preschool science teaching are presented as separate subtitles for each PCK component.

OTS

The results related to teachers' instructional goals for including children in science teaching specific to subject matter selected by them were gathered around the concepts of transfer of knowledge and transfer to daily life. Nevertheless, it was observed that teachers generally knew the curriculum. However, they gave conflicting responses between what they knew and what they planned to do. On the other hand, while Barbara referred to child-centered processes, Gwen mostly referred to teacher-centered processes.

Gwen: *Because the subject of primary colors and intermediate colors is suitable for experimenting, for example, let us say I will teach a value, I will teach love, I cannot do it by experiment, but it is appropriate to teach the intermediate colors and primary colors by experimenting (Interview). There are achievement and indicators in which they need to learn primary colors, there is a plan we should provide the acquisition of which, and if it is written in the plan that I should teach them, I apply them through experiment, which may contribute to them in primary school (LCT).*

Barbara: *As I said in previous questions, I think that children should know that it is night or day, in order words, in order to understand and make sense of time-related concepts and to adapt themselves to daily life accordingly (Interview). We, preschool teachers, have annual plans. Accordingly, I arrange activities by myself and include them in my activity plan. I mean, I act according to my monthly plan (LCT).*

Gwen's responses specific to primary and intermediate color formation subject matter indicated that her instructional goal for preschool science teaching was to acquire achievements. However, although she had general knowledge about the curriculum, her responses revealed that she tended to use the subject as a purpose. Furthermore, she stated that she would take an active role in the experiment during teaching indicated that she had a teacher-centered orientation. Unlike Gwen, Barbara aimed to make knowledge quickly understood and impose it daily to guide children to education. Nevertheless, it was observed that she referred to the interpretation of knowledge, knowledge of curriculum, and the use of different strategies, which also indicated that she had a child-centered orientation.

KSU

It is observed that teachers referred to cognitive maturity in this PCK component, which includes their knowledge about children's learning needs for the subject matter they selected and how children had learning difficulties. In this process, it was revealed that Gwen used traditional approaches, and Barbara mentioned instructional diversity by thinking based on innovation.

Gwen: *Children should know the colors; they should know the primary colors before they can learn intermediate colors; they should be able to express themselves and have sufficient cognitive skills; for example, a child with special needs has difficulty in comprehending this experiment (Interview). They may have difficulty using the materials while experimenting, and they have difficulty learning the colors, so the activity does not take place as desired (LCT).*

Barbara: *They have to reach adequate maturity cognitively. It will not be adequate if I teach verbally. It does not provide permanence for the child as well. Therefore, I will include the children in the process as far as possible, and I also think it would be more effective if I pay attention to using different sources (Interview). It is enjoyable to integrate it with other activities. I use it myself as a science activity and as a Turkish, language, drama, and art activity. I can conduct my activities by integrating based on day and night formation this year (LCT).*

In sample quotations related to KSU, it was observed that Gwen primarily focused on ensuring the readiness of children. Gwen also thought that she could attract children's attention through experiments during the application. In this way, children could quickly obtain the knowledge, which indicated that Gwen never lost her teacher-centered orientation, although she referred to children's cognitive readiness. Barbara, who referred to similar concepts with Gwen, mentioned a teaching process enriched with different subject matters.

KSC

This component represents teacher knowledge about the curriculum specific to the subject matter selected by the participants. It was revealed that the teachers included in the study internalized the curriculum expectations, which enabled them to have achievement-based orientations.

Gwen: *Yes, I think that the achievement related to this activity is given from every matter. There is an indicator in the cognitive or motor area, and I think self-care skills are included sufficiently in the social field. Focusing attention, self-expression, using small muscles, the ability to pour water from glass to glass, self-care skills come to my mind (Interview). I get help from the Internet in this regard. The practice of teaching science education regularly is also not right, yes, I applied it first to raise awareness, but then I gave parents and students responsibility. Because it is tough for me to find, research and apply another science activity every week. There are also other activities we need to do, and it is not easy to spare time to investigate (LCT).*

Barbara: *We can see in that list of achievements and indicators in our national education curriculum, the acquisitions that I have to teach are specific in the process. I organize my activities in a way that children can understand according to those achievements (Interview). We have an achievement indicating that students will be able to sort the events in order of occurrence and explain time concepts. I can also find it from there. So, I think it is enough. The achievements that preschool children can understand are included (LCT).*

Gwen's responses related to KSC indicated that she had known about the curriculum and conceptualized the achievements and indicators. Although she stated that the curriculum was a guide for teachers, she indicated that she mostly resorted to the Internet, not to the curriculum, to save time and overcome her shortcomings in the subject matter. Therefore, it was revealed that Gwen had a general knowledge of the curriculum. However, she contradicted the responses she gave in some situations. She referred to teacher-centered processes since she applied the method of teaching by imposing the duty and responsibility to the child in the process. On the other hand, Barbara could not make sufficient conceptualizations in terms of the curriculum.

KISR

Two significant results can be mentioned in this component, which shows how teachers use their knowledge of instructional strategies and representations. The first is that teachers agreed that children's intrinsic motivation should be high and that their feelings of curiosity should be triggered before teaching. Another result is that Gwen referred to teacher-centered strategies while Barbara referred to child-centered strategies.

Gwen: *When I conduct it, I first start with a story or a play. I conduct integrated activities. Teachers have many shortcomings related to science education and teaching. I also consider myself inadequate, which results from the fact that science activities were never given importance, including universities (Interview).*

Barbara: *As I said, the group I address here is essential. Large group or small group?. Accordingly, I organize my activity process. The size of the model I will use is also important to me. If I address a large group, I make the model big so that all children can see the fields of view and participate. Alternatively, if it is a small group, I prepare something more moderate so that they can see. I make such a preparation (Interview). As I said before, I prepare in advance. I do not conduct the activity suddenly. By moderating in advance, I mean a passive then a dynamic. I try to attract attention. I can use visuals. Alternatively, as I said, it can be a model (LCT).*

Gwen stated that she would include children in integrated science education with different activities specific to the subject matter she selected. However, by making a self-criticism, she argued that the vital importance was not given to science teaching during her undergraduate and postgraduate education. She mentioned that this situation made her feel inadequate, and she referred to teacher competence. On the other hand, Barbara focused on using concrete materials for qualified teaching that may attract the attention of children. She also suggested that integrating science teaching activities with other activities would lead to more effective learning. Therefore, Barbara referred to child-centered processes, increasing intrinsic motivation in teaching, and using different teaching strategies.

KAs

This component represents the measurement and evaluation approaches that the participants consider to include in their process specific to the subject matter they select. Here, it was observed that Gwen referred to traditional measurement and evaluation techniques while Barbara referred to alternative measurement and evaluation techniques.

Gwen: *Questions and answers can be applied, observation, I mean we do not hold an examination. The best measurement and evaluation technique of a teacher in science teaching is observation and question and answer (Interview). With the questions, I examine the activities they conduct. If I have not created any awareness possible, I may fail. I try to teach primary colors in another activity (LCT).*

Barbara: *The main thing is to be able to teach the achievement. To ensure that they can sort the events in order of occurrence. I call children one by one, and I make them use that model. I expect them to act correctly to see whether they can remember and do again what they have learned and heard. I certainly try to make them do it (Interview). I try to focus their attention by chatting, by giving questions in a more fun way rather than by compelling their knowledge (LCT).*

According to sample explanations related to KAs, Gwen indicated that she would perform measurement and evaluation through question and answer and referred to the transfer of knowledge to daily life. On the other hand, Barbara paid attention to children's feelings and thoughts by including them in the process and referred to child-

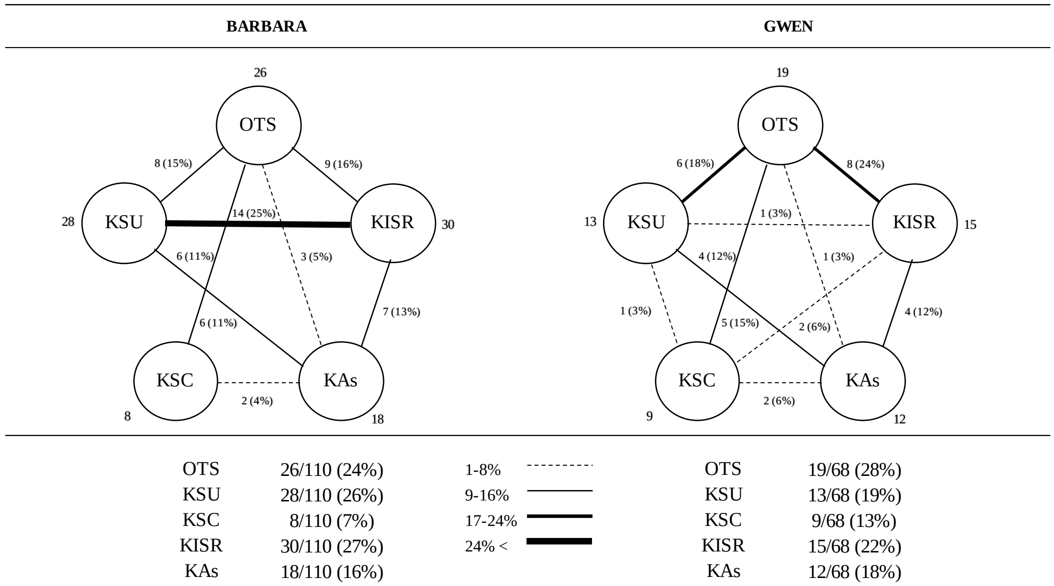

Figure 1 Preschool teachers' PCK map

Table 2 Teaching episodes and connections

	Episodes	Dyad connections among components
Barbara	19	55
Gwen	12	34

centered processes. She also tended to consider knowledge as a means to reach achievements.

3.3 Interaction between PCK Components

In this section, numbers of teaching episodes and dyad connections among components were identified for each teacher firstly were presented (Table 2). Then, PCK Maps of preschool teachers who participated in the study are comparatively summarized in Figure 1.

At first glance, it is observed that Barbara's dyad connections between PCK components were higher than those of Gwen. Accordingly, Barbara's essential components that interacted with other PCK components were KISR, KSU, and OTS, respectively. Furthermore, the interaction between KSU-KISR components was potent. There was no connection between KSU-KSC. This result indicated that Barbara could not complete the pentagon model and was lacking, especially in KSC. Gwen's most crucial component, a more experienced teacher than Barbara that interacted with other PCK components, was OTS. OTS-KSU and OTS-KISR interaction appeared to be stronger than others.

Furthermore, unlike Barbara, Gwen completed the pentagon model and interacted with all components with each other. Teachers' PCK maps also confirm some of the distinctive features of PCK. Accordingly, the integration of components is unique and subject-specific (e.g., Park & Suh, 2015; Smith & Banilower, 2015). For instance, among the teachers who tended towards different matters, Gwen interacted with each PCK component. Barbara tended to integrate strategy and student insights intensively. KSC was the least interactive component compared to other components. However, it can be said that Gwen interacted with KSC more than Barbara.

3.4 Practical Change of Instructional Content

The analysis of the activities based on science teaching performed by preschool teachers in their classes was determined according to the activities within the framework Type of Activity, (PA) Student and Teacher Interactions (P&TI), and Student Study Group (PWG). The results were detailed with the help of Figure 2. Furthermore, observation notes on science teaching conducted by teachers in their classes were also shared.

Gwen: *The activity was started by asking, Shall we experiment with you today?. By showing the finger paints on the table, their names were asked one by one. After asking if it is colored by showing the water in the glasses, let us color this water by taking the blue finger paint with the help of a spoon, putting it in the water, and starting mixing. By stating that the glass next to the blue will remain colorless, it was told let us put the red color in the third glass next to it who wants to do it, and a child assigned randomly among the volunteers was given the task of mixing. By repeating the same process once more, yellow paint was put in the last glass. Then, pieces of napkin were placed between the glasses, and it was waited for a while for the colors to blend into the napkin. After the colors began to blend on the napkin, it was told that the colors in napkins would be intertwined, and "What will happen after the colors are intertwined?" was asked, and after children responded colored napkin, "Would you like that the name of our experiment is a colored napkin?" was asked. After receiving the response yes, children were called from the chairs they were sitting around the table where the experiment was applied. The colors formed in the middle of napkins and how they were formed and primary and intermediate color formation were discussed.*

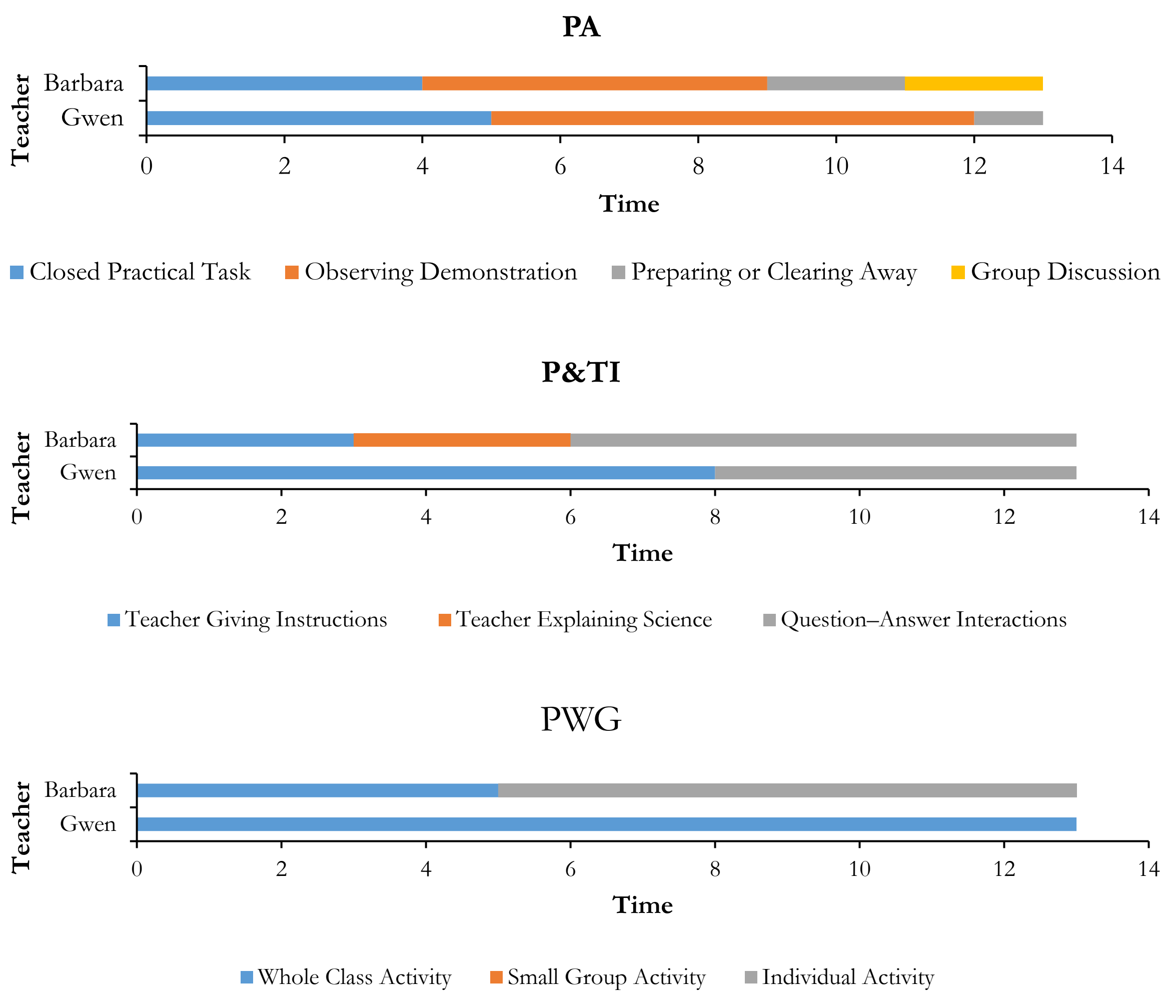

Figure 2 Classroom observations

Barbara: *An intriguing introduction was made. First, children's estimates about what the model could be were obtained, children were directed to questioning by asking if they had previously seen the model figures. Then, in line with the responses obtained, the subject was introduced by enabling children to establish a relationship between the model and the subject. It was talked about the Earth and the Sun. It was continued to inquire on the formation of water, day and night. Then, during this inquiry, the explanation verbally expressed through the model was carried out concretely while explaining that day and night occur as the Earth rotates around the Sun. After explaining the formation of day and night, the children were asked questions linking the subject with everyday life to ensure permanent learning. After the questions of 'What do we do at night? When do we go to school?' were responded by thinking, each child was allowed to examine the model individually. After each child made the formation day and night through the model, the role distribution was made among the children determined in turn by the teacher. While one child was Sun, the other child was asked to animate the Earth. Under the teacher's guidance, the Earth revolved around the Sun while the Sun remained constant. Thus, they knew how the day and night formation took place by using different methods. Children remembered which friends were animating the Sun and Earth by discussing among themselves. They shared their ideas about why the Sun does not revolve around the Earth and how they will live every day or night by communicating. The teacher answered the questions and helped them think and question the activity by including their conversations.*

As shown in observation notes and Figure 2, while participants were applying the lesson plans they created, they generally tended to include the children in individual and large groups in the teacher's teaching and question-answer processes. Furthermore, Barbara conducted less structured activities. On the other hand, it is observed that Barbara adopted a child-centered approach by including children in Group Discussion, a discourse-based dialogical form of interaction. Therefore, it can be said that teachers were more active, and children were in a listener position in the science teaching process as experience increased. This result indicates that preschool teachers' theoretical conceptualizations about science teaching can also be confirmed in practice.

4. DISCUSSION

This study aimed to explore the PCK of two preschool teachers with different professional experiences in science teaching. The analyses performed on qualitative data obtained through lesson plans, PCK interviews, and observations revealed some direct results specific to science teaching in preschool education. First, the knowledge and understanding of preschool teachers about science teaching were limited. This result confirms the results obtained in many studies (e.g., Garbett, 2003; Andersson & Gullberg, 2014; Furman et al., 2019). Teachers argued that the lack of materials (Greenfield et al., 2009) and instructional competence (Saçkes, 2014) affected their teaching. Secondly, Gwen, who is a more experienced teacher, had a more teacher-centered orientation. This orientation affected her strategy and measurement and evaluation processes theoretically and practically (Henze, van Driel, & Verloop, 2008; Käpylä, Heikkenen, & Asunta 2009). Children's learning in the preschool education processes should be mainly performed in play-based situations. Here, preschool teachers' primary role is to create child-based science experiences for children (McCray & Chen 2012). The primary expectation is that the experienced preschool teacher is better equipped in play-based pedagogical strategies than a less experienced teacher (Andersson & Gullberg, 2014). However, Gwen's personal, educational trajectories, beliefs in science, difficulties in science content, and personal starting points about teaching experiences may have differentiated her PCK for science teaching (Arias, Davis, Marino, Kademian, & Palincsar, 2016).

A teacher's PCK for science teaching tends to be affected by variables such as contextual, cultural, and social limitations in the learning environment. Furthermore, teachers learn to teach by being affected by the culture where they grew up (Park & Oliver, 2008). Luft and Zhang (2014) argued that this change took place mainly in the first three years. When teachers face real difficulties during the practice, they usually abandon new practices and return to their teachers' teaching methods. PCK conceptualizations and teaching practices of Barbara and Gwen confirm this argument. Barbara, who had a child-centered orientation, performed her teaching practices by following this orientation. However, OTS-KISR interaction on Barbara's PCK map was not very strong. On the other hand, Gwen also reflected her teacher-centered orientation to the selection of strategy. Unlike Barbara, this situation was reflected in the OTS-KISR interactions in the PCK map with the effect of Gwen's experience.

Thirdly, although Barbara tended to use more child-centered orientation and strategies than Gwen, she was inadequate in contextualizing science teaching with the preschool education curriculum. This result confirms that professional experience helps to integrate the knowledge of the curriculum with other PCK components. When teachers' PCK maps were compared, Gwen completed the pentagon model. Barbara could not complete the connection between KSC and KSU. Therefore, when it is considered that the quality of PCK depends on consistency between components and power of individual components, it can be said that Gwen's quality of PCK was better (Park & Chen, 2012). Furthermore, this result is consistent with the findings of studies conducted in other contexts (Friedrichsen et al., 2009; Kleickmann et al., 2013).

The knowledge of curriculum that Shulman (1987) excluded from PCK was considered as a component that complemented the PCK by Grossman (1990) and Magnusson et al. (1999). When it is considered in terms of the preschool education context, the teacher's main role is not to give the scientific concepts directly to the children but to give them scientific process skills with the help of achievement-based and play-based activities. Therefore, knowledge of curriculum has extra importance in preschool education (Cairney, 2002). On the other hand, Faulkner-Schneider (2005) emphasized that preschool teachers should not consider science an addition or a separate part of the early childhood program and should integrate science activities into a natural play-based curriculum. However, teachers' knowledge of the curriculum had the most limited connection with other components. This result indicates that preschool teachers could not adequately contextualize their knowledge of the curriculum regarding science teaching. Teachers were able to say the MoNE (2013) preschool curriculum achievements when they were asked. However, they indicated that they had difficulty associating these achievements with appropriate science concepts, which confirms that teacher efficacy is an influential member of PCK (Park & Oliver, 2008). Finally, although two teachers' theoretical and practical conceptualizations about measurement and evaluation in preschool science teaching were generally limited, they tended to be affected by their orientation (Park & Chen, 2012). Assessment in preschool education should be performed through individualized activities to support the functioning, learning, and thinking of children in cognitive, social, physical, and emotional development (Brenneman, 2011). The teacher's role here is to include the child in the negotiation processes with a child-centered orientation. To overcome this difficulty requires teachers to understand child development and the expected learning sequences in multiple areas (Gelman, Brenneman, Macdonald, & Román, 2009). This study indicated that two teachers also tended towards traditional measurement and evaluation techniques and did not know complementary measurement and evaluation techniques. They could not go beyond asking questions during their practices.

5. CONCLUSION

Results revealed that teachers did not have sufficient knowledge about science teaching and that their PCK tended to change according to professional experience. It was determined that experienced teachers had more teacher-centered orientations than less experienced teachers who had more student-centered orientations. Moreover, it was observed that professional experience increased the relationship between the PCK components.

In brief, the results obtained are similar to some results of the studies in similar or different contexts in the literature but different from some other results, which reveals that science teaching within preschool teacher education should be re-evaluated with its unique characteristics. This will only be possible by discussing teachers' PCK, which is the implicit form of professional knowledge, from different aspects and specific to preschool education. Therefore, the following suggestions can be made especially in terms of contributing to preschool education literature: (a) Attention can be focused on practical applications for preschool science teaching in the preservice education process. (b) Preservice science teaching courses can be conducted by contextualizing them with the curriculum. (c) New studies can be designed to determine the limits of teachers' PCK for inquiry-based science activities in the preservice and in-service preschool teaching processes. (d) The number of studies to explore the individual components of the PCK of teachers within preschool science education can be increased. Through these suggestions, richer reasoning and future projections related to preschool teachers' PCK structures can be developed.

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