



## Mathematics in Early Education: Evaluating the Pedagogical Content Knowledge of Turkish Pre-service Preschool Teachers\*

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Article Information	ABSTRACT
Received: 03.06.2025	This study aims to explore the pedagogical content knowledge levels of mathematics among pre-service preschool teachers in terms of various variables. The working group involved a total of 262 pre-service teachers, comprising 152 individuals in the 2 <sup>nd</sup> grade and 110 in the 4 <sup>th</sup> grade, studying in the preschool teaching program at four distinct state universities in Turkey. The study employed the relational survey model, utilizing "Pre-service Teachers Information Form" and "Preschool Education Teachers' Pedagogical Content Knowledge Scale on Mathematics" as data collection instruments. The findings demonstrated that pre-service teachers exhibited close to high level of pedagogical content knowledge in mathematics. The content areas in which pre-service teachers provided the most correct answers were counting, matching, and graphing, while processes were found to be particularly associated with communication and association. Pre-service teachers' pedagogical content knowledge of mathematics did not differ significantly across grade levels. On analysing the content and processes separately based upon grade levels, a significant difference favouring fourth graders was identified, particularly in matching, pattern, and classification. However, no significant difference was observed in processes concerning grade levels. The participants' pedagogical content knowledge of mathematics did not significantly vary across the universities they attended. <b>Keywords:</b> Preschool education, pedagogical content knowledge, mathematics, content, process
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### 1. INTRODUCTION

Considering multiple reports prepared in recent years, there has been a resounding expression of concerns related to education systems and teacher quality (Australian Council of Deans of Education, 2012; Australian Institute for Teaching and School Leadership, 2011; European Commission/EACEA/Eurydice, 2018; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2015). In this regard, Organisation for Economic Co-operation and Development (OECD) carried out a comparative analysis of the education policies of member countries between 2008 and 2014, highlighting the fundamental role of teacher quality in the development of educational institutions (OECD, 2015). Furthermore, in terms of teacher quality, the early childhood period has become the most important stage for all countries, as it is the period when children develop most rapidly and acquire fundamental skills, attitudes, and behaviors (Education Reform Initiative [ERG], 2015; Turkish Education Association Think Tank [TEDMEM], 2024).

The research results on the functioning of the brain in early childhood and the initial phase of the educational process reveal the importance of the first years in brain development (National Scientific Council on the Developing Child, 2007). These studies

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also underscore the strong ties between the literacy and mathematics development of young children, thus demonstrating the contributions of investing in quality early childhood to the nation, family and children (Heckman & Masterov, 2007). Under the strength of the recognition of mathematical thinking as a crucial quality to be cultivated in all individuals within 21st-century education systems, the significance of starting mathematics education in the early years of childhood and teachers' competencies in this domain become apparent (Claessens & Engel, 2013; Dağlıoğlu, 2020; Linder et al., 2013). Notably, when training future preschool teachers, it is of great importance to determine the requisites of early childhood mathematics education and how this information can be transformed into instructional practices that enhance children's learning (Hammerness et al., 2005; Leavy & Hourigan, 2018).

When the preschool teaching undergraduate program in Turkey is examined, this program first came into force in 1997, was updated in 2006 and 2018, and program update studies were transferred to universities with the transfer of authority carried out by Council of High Education in 2020 (CHE, 2020). Teacher candidates take many courses related to the teaching profession, general culture, and subject expertise throughout their undergraduate program. One of these courses is 'Mathematics Education in Early Childhood'. This course is mostly taught theoretically for three hours, both in its updated form in 2018 and after it was left to the discretion of universities in 2020 (see Gazi University., Hacettepe University) This course generally covers the definition and importance of mathematics in early childhood, principles and standards in mathematics education; techniques and methods for teaching mathematical concepts and scientific thinking skills; mathematics education and games; Mathematics programs such as Building Blocks, STEM, and GEMS; the acquisition of basic mathematical concepts, mathematical content, and skills (problem solving, mathematical skills, numbers and counting, stages of teaching the concept of numbers, symbols, operations, geometry, spatial orientation, measurement, data analysis-graphs/probability); planning and implementation of mathematical activities (CHE, 2018). In other words, the course aims to provide a rich learning experience through different mathematics programs by interweaving mathematical content and processes in mathematics education.

### **1.1. Pedagogical Content Knowledge (PCK) in Early Mathematics**

Teacher training programs are structured on content or subject knowledge and pedagogical knowledge (Setyaningrum et al., 2018). In this regard, pedagogical approaches that aid the development of children's mathematical skills are effective in enhancing those skills (Mononen & Aunio, 2013). For effective mathematics education, teachers must first possess a good level of PCK (Jang, 2013). PCK in education encompasses the understanding of what to teach to specific age groups and the skill to integrate this knowledge with effective teaching method (Shulman, 1986), meaning that the teacher creates an effective and efficient learning-teaching environment for children. McCray (2008) pointed out that PCK in mathematics education is the intersection of the questions "Who will teach?, What will be taught?, How will it be taught?". This understanding of PCK enables teachers to discern the age-appropriate mathematical content for their students and employ effective teaching strategies in delivering these concepts. McCray (2008) suggests that PCK for preschool teachers considerably influences children's learning. Moreover, Lee (2010) concludes that PCK in mathematics education increases the quality of basic teacher education. Research has demonstrated that children exhibit a remarkable capacity for learning and structuring complex mathematical understanding when exposed to meaningful educational experiences in early childhood educational settings (Chen & Li, 2014; Clements & Sarama, 2011), and that those with stronger early arithmetic skills are more confident in mathematics as they progress into later stages of education (Chang, 2023). Research on teachers has uncovered variations in approaches to mathematics instruction, with pedagogically conscious practices being associated with the advancement of children's early mathematical skills (Lugo et al., 2019; MacDonald & Murphy, 2019; Padilla et al., 2025). In this context, pre-service teachers' PCK in mathematics has become the focal point of the education process.

The relevant literature on pre-service preschool teachers lacks studies on mathematics education, yet recent research suggests that pre-service teachers may not possess sufficient knowledge in this area (Chen et al., 2014; Goldrine Godoy et al., 2021; Korkmaz & Şahin, 2019; Li, 2021; Markovits & Patkin, 2020; Torbeyns et al., 2020). In this context, the study conducted by Samuel Sánchez et al. (2015) highlighted difficulties among pre-service preschool teachers in understanding children's mathematical thinking, contributing to a noted deficiency in PCK concerning mathematics among these candidates. However, effective teacher education programs that provide practical experiences such as classroom observations, internships, and teaching practicums, which enable teacher candidates to gain real-world experience, lead them to feel more confident and competent in their mathematics teaching skills (Fuentes-Abeledo et al., 2020; Leigh, 2024). Preschool pre-service teachers must not only be knowledgeable but also aware of ways to create appropriate math learning opportunities for young children (Thornton et al., 2009). Indeed, studies on this subject have revealed that teachers who have completed their undergraduate programs and joined the workforce are significantly more likely to adopt effective practices and acquire more advanced knowledge related to these practices if they have more extensive experience and specialized training in children's mathematical development (Leavy & Hourigan, 2018; Lee, 2010; Platas, 2008). Various studies suggest that teachers are more likely to adopt effective practices and gain knowledge related to these practices. Thus, it is of importance for pre-service preschool teachers to incorporate current instructional approaches into both the theoretical and practical aspects of mathematics education. Furthermore, future teachers need PCK to determine the content and processes essential for their learning in mathematics education. This study also examined whether there was a difference between teacher candidates' PCK of mathematics when they first received their mathematics education and when they were in their final year (when they were given the opportunity to put the theoretical knowledge they acquired in their teaching practice course into practice). Thus, answers to the following questions were sought:

1. What levels of PCK do pre-service teachers possess in mathematics?
2. What is the knowledge level of pre-service teachers in mathematics content and processes?
3. Do pre-service teachers' PCK levels in mathematics vary significantly across grade levels?
4. Do pre-service teachers' knowledge levels in mathematics content and processes vary significantly across grade levels?
5. Do pre-service teachers' PCK levels in mathematics vary significantly across the university they attend?

## 2. METHODOLOGY

A descriptive survey research design is employed to examine the PCK of pre-service preschool teachers in mathematics across various variables. The study aims to describe existing levels and reveal the differences between groups, it falls within the scope of the descriptive survey model (Creswell, 2012).

### 2.1. Participants

Participants encompassed a total of 262 pre-service teachers, consisting of 152 second graders and 110 fourth graders in preschool teaching programs. A combination of convenience sampling and criterion-based purposive sampling methods was utilized for sample selection. First, the sample of the study comprised participants selected via convenience sampling from pre-service teachers enrolled in four state universities with a minimum of seven years' experience in graduating students in the field of early childhood education. The sample specifically included second-year pre-service teachers enrolled in the updated 2018 preschool undergraduate program who had successfully completed the mathematics course, as well as fourth-year students in their final semester before graduation who were taking the teaching practice course.

Table 1.

*Demographic Information Regarding the Participants*

	<b>Group</b>	<b>F</b>
Gender	Female	204
	Male	58
Age	18-20	69
	21-23	142
	24-26	28
	27 and over	23
Grade Level	2 <sup>nd</sup> grade	152
	4 <sup>th</sup> grade	110
The University	U1	64
	U2	72
	U3	57
	U4	69
<b>Total</b>		<b>262</b>

### 2.2. Data collection tools

The study deployed *Pre-service Teacher Information Form*' and *'Preschool Teachers' Pedagogical Content Knowledge regarding Mathematics Scale (PMPCK)*' as data collection tools. The data collection tools were administered through face-to-face interviews.

*The Pre-service Teacher Information Form* was developed by the researchers and included demographic details such as age, gender, the university attended by the participants, etc.

*Preschool Teachers' Pedagogical Content Knowledge regarding Mathematics Scale (PMPCK)* was developed by Dağlı, Dağlıoğlu and Atalmış (2019). This tool incorporates mathematical content and processes, aligning with the National Council of Teachers of Mathematics (NCTM, 2000) standards, through five case studies. These case studies are developed with dialogues between children engaged in games, covering various mathematical content and processes. Each case study consists of seven items. Each case included in the scale consists of seven items, and participants are expected to identify the mathematical content and processes present in each item. For instance, in Case 1, participants are asked to indicate which mathematical contents —such as counting, geometry, spatial perception, part-whole relationships, matching, classification/grouping, comparison, ordering, measurement, operations, patterns, and graphs—are reflected in the statement "Gül says, 'Let's play with the cards in the drawer.'" Furthermore, they are required to specify which mathematical processes are involved, including communication, making connections, reasoning and proof, problem solving, and representation/visualization.

Content and structure validity were examined to ensure the validity of the scale, and both exploratory and confirmatory factor analyses were conducted. The internal consistency coefficient (Cronbach Alpha) of the scale was determined as .95. The results affirm the scale's validity and reliability as a measurement tool. In this study, the internal consistency coefficient (Cronbach Alpha) of the scale for pre-service teachers was calculated as .93. To test the construct validity, the same model developed by

Dağlı et al. (2019) was conducted applying confirmatory factor analysis via MPlus 7.4 program. Evaluation of fit indices from the analysis revealed that the CFI and TLI values were greater than .90 and .90, and the RMSEA and SRMR values were below .08, indicating an acceptable model fit ( $\chi^2 (554,262) = 947.137$ ; CFI = .93; TLI = .92; RMSEA = .04; SRMR = .04). Teachers' score ranges and levels in the scale were determined as 5 levels, aligning with TIMMS (International Mathematics and Science Trends Research) data. The determination of score ranges on the scale was guided by grouping the level ranges based on TIMMS data, as illustrated in Table 2 (TIMMS, 2015).

Table 2.  
*Teachers' Scores and Level Ranges on PMPCK in Mathematics*

Level	Score
Below Low	1-7
Low Level	8-14
Intermediate	15-21
High Level	22-27
Advanced Level	28-35

Each sentence within the scale addresses one or more mathematical content/processes. Each item in the scale is evaluated as 1 point. Given that each case study consists of 7 items, an entire case study is worth 7 points. The entire scale is calculated based on 35 points. Thus, a teacher with the highest score in total demonstrates a high level of PCK.

### 2.3. Data Analysis

This study investigated whether pre-service teachers' PCK in mathematics demonstrated a normal distribution. In assessing normality, the skewness value of the distribution was examined. If the skewness value falls between -1 and +1, the distribution is considered normal (Field, 2009). The results indicate that the skewness coefficient scores for each sub-dimension of the scale lie within the range of -1 and +1, except for spatial perception (1.87), part-whole relationship (2.68), classification/grouping (1.42), and processing (2.39). Therefore, this study employed parametric tests for each dependent variable showing a normal distribution, and non-parametric tests for those that did not exhibit normal distribution (Genç & Soysal, 2018). Descriptive statistics were used to calculate the PCK levels of pre-service teachers regarding mathematics.

## 3. FINDINGS

The findings of the study, which was conducted to discern the PCK levels of pre-service teachers enrolled in preschool teaching undergraduate programs across four different universities in Turkey, are outlined below in line with the research questions.

### 3.1. PCK levels of pre-service teachers

Table 3.  
*PCK Levels of Pre-Service Teachers in Mathematics*

PCK Levels in Mathematics	N	$\bar{X}$	sd
	262	21.79	2.30

As in Table 3, the evaluation of PCK levels among pre-service teachers regarding mathematics suggested that the mean total scores for both second and fourth graders were close to the high level ( $\bar{X} = 21.79$ ).

Table 4.  
*Pre-Service Teachers' Knowledge Levels in Mathematics Content and Processes*

	Total content number	Mean number of correctly answered content	%	sd	Total content number	Mean number of correctly answered content	%	sd			
	N	$\bar{X}$			N	$\bar{X}$					
Content in Mathematics	Counting	26	11.18	43	5.41	Mathematical Processes	Communication	35	11.9	34	1.1
	Pairing	8	3.32	42	1.63		Association	7	2.38	34	2.09
	Graphic	2	0.8	40	0.79		Reasoning	8	2.48	31	2.0
	Geometry	13	4.16	32	3.51		Problem solving	14	4.06	29	2.9
	Comparison	7	1.28	32	1.71		Representation	5	1.45	29	1.33
	Measuring	10	2.9	29	2.03						
	Ordering	6	1.44	24	1.29						
	Patterning	5	1.1	22	1.13						
	Classification/Grouping	7	0.77	11	0.97						
	Spatial Perception	10	1.00	10	1.53						
	Process	6	0.6	10	1.12						
	Part-Whole	5	0.45	9	0.86						

Table 4 depicts that pre-service teachers predominantly provided correct answers to questions related to counting (43%). Other mathematics content areas that pre-service teachers answered correctly included matching (42%), graphics (40%), geometry (32%), comparison (32%), measurement (29%), ordering (24%), pattern (22%), classification (11%), spatial perception (10%), processing (10%) and part-whole (9%), respectively. Therefore, pre-service teachers were identified to excel the most in answering counting questions correctly and performed comparatively less well in questions related to part-whole relationships. As for the findings regarding the participants' knowledge levels in mathematical processes, pre-service teachers were observed to provide correct answers to 34% of the questions related to mathematical processes involving communication and association. The mathematical processes for which pre-service teachers answered correctly included reasoning (31%), problem solving (29%) and representation (29%), respectively. Hence, it is most probable that pre-service teachers answered questions related to communication and association the most accurately, while performing relatively less well in questions related to problem solving and representation.

### 3.2. Pre-service teachers' PCK in mathematics across grade levels

Table 5.

*Distribution of Pre-Service Teachers' PCK in Mathematics Across Grade Levels*

Grade Level	N	$\bar{X}$	sd	df	t	p	Cohen's d
2 <sup>nd</sup> grade	152	21.68	2.32	260	.87	.381	-
4 <sup>th</sup> grade	110	21.94	2.25				

Table 5 displays that pre-service teachers' PCK levels in mathematics did not differ across their grade levels (2<sup>nd</sup> graders  $\bar{X}$ =21.68, standard deviation=2.32; 4<sup>th</sup> graders  $\bar{X}$ =21.94, standard deviation=2.25). Notably, no statistically significant difference was identified across pre-service teachers' PCK levels in terms of their grade levels ( $t(260)=.87, p>.05$ ).

Table 6.

*Distribution of Pre-Service Teachers' Knowledge of Mathematics Content Across Grade Levels (Parametric Tests)*

Math content	Grade level	N	$\bar{X}$	sd	df	t	p	Cohen's d
Counting	2 <sup>nd</sup> grade	152	11.15	5.73	260	0.01	.985	-
	4 <sup>th</sup> grade	110	11.14	4.95				
Geometry	2 <sup>nd</sup> grade	152	4.32	3.44	260	0.72	.468	-
	4 <sup>th</sup> grade	110	4.00	3.60				
Matching	2 <sup>nd</sup> grade	152	3.03	1.55	260	-4.35	.000*	0.53
	4 <sup>th</sup> grade	110	3.89	1.61				
Comparison	2 <sup>nd</sup> grade	152	2.16	1.73	260	-0.50	.614	-
	4 <sup>th</sup> grade	110	2.27	1.68				
Sorting	2 <sup>nd</sup> grade	152	1.44	1.32	260	-0.36	.716	-
	4 <sup>th</sup> grade	110	1.50	1.26				
Measuring	2 <sup>nd</sup> grade	152	2.93	2.18	260	0.06	.950	-
	4 <sup>th</sup> grade	110	2.91	1.79				
Pattern	2 <sup>nd</sup> grade	152	1.00	1.07	260	-2.06	.040*	0.25
	4 <sup>th</sup> grade	110	1.29	1.19				
Graphic	2 <sup>nd</sup> grade	152	0.78	0.76	260	-0.44	.655	-
	4 <sup>th</sup> grade	110	0.82	0.83				

\* $p<.05$

As seen in Table 6, the mean scores from matching and pattern content questions differed across grade levels. Fourth graders demonstrated a notably higher mean score on matching questions ( $\bar{X}$ =3.89, standard deviation=1.61) than second graders ( $\bar{X}$ =3.03, standard deviation=1.55) ( $t(260)=-4.35, p<.05$ ). The effect size was found to be moderate (Cohen's  $d = .53$ ). Likewise, the fourth graders exhibited a higher mean score on pattern content questions ( $\bar{X}$ =1.29, standard deviation=1.19) compared to their second-grade counterparts ( $\bar{X}$ =1.00, standard deviation=1.07) ( $t(260)=-2.06, p<.05$ ), which was found in favour of fourth graders. The effect size was found to be small (Cohen's  $d = .25$ ).

Table 7.

*Distribution of Pre-Service Teachers' PCK Across Grade Levels (Non-Parametric Tests)*

Math content	Grade level	N	Rank average	Rank sum	Mann Whitney U	p	Cohen's d
Spatial perception	2 <sup>nd</sup> grade	152	127.48	19377.00	7749.00	.268	-
	4 <sup>th</sup> grade	110	137.05	15076.00			
Part-whole	2 <sup>nd</sup> grade	152	129.83	19734.50	8106.50	.602	-
	4 <sup>th</sup> grade	110	133.80	14718.50			
Classification/grouping	2 <sup>nd</sup> grade	152	122.33	18593.50	6965.50	-.012*	0.17
	4 <sup>th</sup> grade	110	144.18	15859.50			

Process	2 <sup>nd</sup> grade	152	129.72	19717.00	8089.00	.596	-
	4 <sup>th</sup> grade	110	133.96	14736.00			

As seen Table 7, the mean scores of pre-service teachers on classification/grouping questions ( $U=6965.50$ ,  $p<.05$ ) significantly varied in favour of the fourth graders. The effect size was found to be small (Cohen's  $d = .17$ ). Conversely, no statistically significant difference was noted in mean scores across other questions in terms of grade levels.

Table 8.

*Distribution of Pre-Service Teachers' Knowledge of Mathematics Processes in Terms of Grade Levels*

Math process skills	Grade level	N	$\bar{X}$	sd	df	t	p	Cohen's d
Communication	2 <sup>nd</sup> grade	152	11.66	3.60	260	.25	.797	-
	4 <sup>th</sup> grade	110	12.01	3.02				
Association	2 <sup>nd</sup> grade	152	2.26	2.01	260	.93	.343	-
	4 <sup>th</sup> grade	110	2.51	2.19				
Reasoning	2 <sup>nd</sup> grade	152	2.40	2.10	260	.58	.561	-
	4 <sup>th</sup> grade	110	2.55	1.87				
Problem solving	2 <sup>nd</sup> grade	152	3.78	3.03	260	1.36	.175	-
	4 <sup>th</sup> grade	110	4.28	2.68				
Representation	2 <sup>nd</sup> grade	152	1.48	1.35	260	.19	.847	-
	4 <sup>th</sup> grade	110	1.45	1.29				

Table 8 portrays that the mean scores obtained by pre-service teachers in the questions on communication ( $t(260)=.25$ ,  $p>.05$ ); association ( $t(260)=.93$ ,  $p>.05$ ); reasoning ( $t(260)=.58$ ,  $p>.05$ ); problem solving ( $t(260)=1.36$ ,  $p>.05$ ) and representation ( $t(260)=.19$ ,  $p>.05$ ) did not exhibit a significant difference concerning grade levels.

### 3.3. Pre-service teachers' PCK levels across the university

Table 9.

*Descriptive Statistics Related to Pre-Service Teachers' Scores from PMPCK in Terms of the University They Attend*

University	N	$\bar{X}$	sd
U1	64	21.24	2.14
U2	72	22.29	1.88
U3	57	21.96	2.58
U4	69	21.66	2.50
<b>Total</b>	<b>262</b>	<b>21.79</b>	<b>2.30</b>

Table 9 demonstrates the mean and standard deviations of the scores derived from the PCK scale among pre-service teachers studying at different universities. Notably, The findings indicate that the mean scores of the pre-service teachers are closely aligned.

Table 10.

*Distribution of Pre-Service Teachers' PCK Levels Across the University They Attend*

Source of variance	Sum of squares	df	Mean of squares	F	p
Between groups	40.05	4	13.35	2.57	.05
Within groups	1336.37	258	5.18		
Total	1376.42	261			

As displayed in Table 10, the mean scores of the pre-service teachers on the PCK scale related to mathematics did not differ significantly concerning the university they attend ( $F(3,258)=2.57$ ;  $p>.05$ ).

## 4. RESULTS, DISCUSSION AND RECOMMENDATIONS

The findings obtained in this study are discussed under the headings of pre-service teachers' PCK levels, pre-service teachers' PCK in mathematics across grade levels, and pre-service teachers' PCK levels across the university.

### 4.1. PCK levels of pre-service teachers

This study analysed the levels of PCK among pre-service preschool teachers in mathematics. The results suggested a high level of PCK among the participants. Similarly, Demirbaş (2019) investigated the PCK levels of pre-service preschool teachers in mathematics and observed a consistently elevated level of proficiency in their PCK. Umay (2003) concluded that pre-service preschool teachers' content knowledge in mathematics education was insufficient; on the other, Bilgen and Öztürk (2023) found that pre-service pre-school teachers' PCK in mathematics education was medium level. Also In Hong (2013) noted that pre-service preschool teachers and in-service teachers were cognizant of their roles and responsibilities in children's mathematics learning, yet they needed training in PCK of mathematics. Considering these findings, it is most likely that factors such as the

quality of the "Mathematics Education in Early Childhood" course offered at the universities where the participants attend, the interest of pre-service teachers in mathematics, and their own mathematics background during their education may have been effective in the emergence of this result.

With regard to the knowledge levels of pre-service teachers regarding mathematics content and processes, the topics in which the pre-service teachers provided the highest number of accurate answers were related to counting, matching and graphing, respectively. Conversely, the subjects with the fewest correct answers involved part-whole, operations, spatial perception and classification. This pattern may stem from the dominance of number-focused activities in early childhood curricula, where mathematics is often equated with counting and numeracy. Consistent with this interpretation, previous studies reported that preschool mathematics instruction tends to overemphasize numerical skills while providing limited opportunities for exploring spatial and relational concepts (Baki & Hacısalıhoğlu Karadeniz, 2013; Orçan Kaçan & Halmatov, 2017; Pekince & Avcı, 2016; Thiel, 2010; Yazlık & Öngören, 2018). In a parallel vein, Lee (2010; 2017) implicated that teachers had high PCK in counting, measuring, classification and pattern; whereas, their PCK appears to be comparatively lower regarding geometry, spatial perception and comparison, referring to a need for further knowledge and experience in these areas. This may indicate that pre-service teachers with limited professional experience should do more practice in classification, spatial perception, operation and part-whole, particularly where their correct responses are fewer. Besides, comparable findings from studies involving actively practicing teachers imply that educators, both in training and already in the profession, should engage in activities covering diverse mathematical content to enhance their proficiency across various domains.

As regards the mathematics processes, pre-service teachers exhibited the highest accuracy in responses related to communication and association, while their least accurate responses were associated with problem-solving and representation. Mathematical communication enables expressing mathematical thought using language in a clear, precise and concise manner (NCTM, 2000). Language serves as a useful communication tool for learning mathematics (Morgan et.al., 2014). The current literature lacks studies conducted on the mathematics processes of pre-service teachers. However, a study revealed a positive relationship between teachers' PCK of mathematics and their use of mathematics-related language (McCray, 2008). The present study suggested that the high mean scores in communication skills among pre-service teachers may be due to their correct use of mathematical language.

The high level of this skill among pre-service preschool teachers can be attributed to adeptness at linking mathematics to daily life and their ability to integrate mathematics with other skills. Because mathematical thoughts and mathematical skills enhance the durability of mathematics learning when associated with other skills and previous experiences (Argın & Dağlıoğlu, 2020; NCTM, 2000).

In general, pre-service teachers were identified to have varying levels of knowledge about mathematics content and processes. At this point, scientists not only investigate the relationship between the learning process in early childhood and 'who, what and how will learn?', but they also emphasize the crucial role of pedagogical practices in guiding children to explore, inquire, and acquire specific skills. These practices aim to foster a child's curiosity and desire to learn (Stephen, 2010). In this regard, planning activities that address mathematical content and processes together during the teacher education process will help pre-service teachers enrich their mathematics education skills and handle diverse content and processes.

#### **4.2. Pre-service teachers' PCK in mathematics across grade levels**

The findings also suggested that the PCK levels of pre-service teachers in mathematics did not differ significantly across grade levels. However, descriptive statistics revealed that the PCK levels of fourth-graders were slightly higher than the second-graders. The effect sizes obtained offer valuable insights not only into the statistical significance of the differences between grade levels but also into the practical magnitude of these differences. The moderate effect size observed for the matching tasks suggests that the difference between fourth- and second-grade students is educationally meaningful. Conversely, the small effect size for pattern-related items indicates that, although the difference is statistically significant, its practical implications may be limited. These results suggest that fourth-grade students exhibit more advanced conceptual development in specific mathematical domains; however, the extent of this advancement varies across different content areas.

In the updated Preschool Teaching Undergraduate program by CHE (2018), a theoretical course titled 'Mathematics Education in Early Childhood' has been incorporated with three hours of instruction per week. Given that pre-service teachers undergo training within this program, it is likely that although participants have a high level of knowledge about mathematics education, their chances of experiencing this knowledge may be constrained and thus limiting their overall gains. Besides, criticisms have been raised regarding factors impacting the quality of undergraduate programs that train early childhood educators. These include the scarcity of studies on such programs and the insufficient number of faculty members specifically trained in the field within these programs (Gilken et al., 2023; Rockel, 2014). Likewise, Konca and Özçakır (2021) concluded that there was no significant difference between the grade level of pre-service preschool teachers and their PCK levels in mathematics. Consistent with previous research, this finding partially aligns with the results of Bilgen and Öztürk (2023); however, in the present study, pre-service teachers demonstrated higher levels of PCK, possibly due to differences in university contexts and course implementation practices.

When the mathematics content and processes of the prospective teachers were examined separately in terms of grade level, the scores of the fourth grade pre-service teachers in terms of content matching, pattern and classification were significantly higher than those of the second graders. However, no significant difference was observed in the processes based on grade levels. Higher scores in matching, pattern and classification among fourth graders can be explained by the increase in their experience as a result of practicing in fourth grade classrooms during the Teaching Practice course in both semesters.

### 4.3. Pre-service teachers' PCK levels across the university

Upon analysing the PCK levels of pre-service preschool teachers regarding mathematics in terms of the university they attend, no statistically significant difference was identified among them, and the mean score for those in U3 was higher. This may be due to the fact that faculty members deliver mathematics education courses with similar content and processes during the process of training pre-service teachers. In addition, the opportunities for these teachers to apply the knowledge they have acquired are quite limited. However, in contrast to these findings, Leigh (2024) reported that pre-service early childhood teachers in Southwestern Nigeria demonstrated low levels of mathematical PCK across all five dimensions—content knowledge, instructional practices, classroom management, communication, and assessment. It is attributed to insufficient coursework in early mathematics, limited practical exposure, and lack of mentoring opportunities. This contrast highlights the potential influence of teacher education program design, institutional resources, and mentoring quality on the development of pre-service teachers' PCK.

The significance of mathematics education during early childhood becomes evident in its substantial influence on children's success in later years. This underscores the critical role of teachers' PCK in determining teaching quality and fostering children's learning gains (Kunter, 2013). Considering the impact of early childhood mathematics education on children's future academic success, the importance of preschool teachers being equipped with certain competencies in terms of knowledge, skills and attitudes becomes apparent (Mukandayambaje & Maniraho, 2021). Engaging with children in early childhood requires specialized training and sensitivity as stated in official curricula (Gilken et al., 2023). Hence, it is crucial to critically examine curriculum and to develop alternative theoretical frameworks to better comprehend how it can be evaluated (Wood & Hedges, 2016). This evaluation is related to the performance of teachers in the learning process and the PCK they possess (Blömeke et al., 2015). Throughout the teacher training process, the training provided for mathematics education, the practices carried out, and the professional skills gained by pre-service teachers are decisive for shaping their PCK. In this context, it would be beneficial to enhance the competence, knowledge and skills of pre-service teachers in mathematics education, and to provide more practical training, particularly focusing on mathematical content and processes as well as the use of mathematical language. Also, mathematics education courses in early childhood teacher education programs should be designed to provide stronger connections between theoretical knowledge and practical classroom applications. Incorporating more hands-on activities, problem-solving tasks, and real-life teaching simulations could help pre-service teachers apply mathematical concepts more effectively. Since the findings revealed that knowledge about mathematical processes (such as reasoning, problem solving, and communication) did not significantly differ by grade level, course content should place greater emphasis on process-oriented learning experiences. Embedding opportunities for mathematical reasoning, discussion, and reflection may strengthen this aspect of PCK. The similarity of results across universities suggests a need for revising the mathematics education curricula in early childhood teacher preparation programs. Universities could collaborate to develop a unified framework that integrates both content and process standards, ensuring a balanced and comprehensive approach to mathematics education.

The study is limited to the mathematical content and processes specified in the scale, as well as to the case studies included within this instrument. Therefore, the findings should be interpreted within the scope of the mathematical domains and process skills addressed in the measurement tool. Future research should include additional process skills to develop a more comprehensive understanding of pre-service teachers' PCK. Moreover, using multiple data collection methods, including classroom observations, lesson analyses, and interviews, could provide deeper insights into how theoretical knowledge is reflected in teaching practices.

In addition, the study is limited to students enrolled in the preschool teaching undergraduate program updated in 2018 at four state universities in Türkiye that have been involved in the teacher education process for at least seven years and have produced graduates. Consequently, the findings may not be generalizable to all early childhood teacher education programs or to institutions with different program structures. Future studies are recommended to include a more diverse sample by involving newly established universities, private universities, and programs from different geographical regions. Conducting comparative analyses across various institutional and curricular contexts could yield valuable insights into how differences in program design, faculty experience, and educational policies influence pre-service teachers' PCK and professional growth.

Finally, future research should include pre-service teachers from all grade levels rather than focusing solely on second- and fourth-year students. This approach would allow for examination of the progression of PCK over time, identify key stages in its development, and provide a clearer picture of how the cumulative effects of theoretical instruction and practical experiences contribute to professional growth. Longitudinal studies tracking the same cohort across multiple years could be particularly informative in understanding the effectiveness of curriculum sequencing and pedagogical training throughout the program.

## 5. CONCLUSION

According to the research findings, the PCK levels of pre-service teachers are generally above average. In terms of mathematical content, their knowledge levels are particularly high in counting, matching, and graphs; while in terms of process, their knowledge levels are high in communication and relating. This result shows that pre-service teachers' knowledge of mathematical content and processes has developed at different levels.

When examined by grade level, no statistically significant difference was found in the overall PCK scores. However, it was observed that the mathematics-related PCK levels of final-year pre-service teachers were higher than those of second-year students who had just started the course. In particular, the scores of senior students were significantly higher in the topics of matching, pattern, and classification. In contrast, no significant difference was found in the process dimension according to grade level.

Furthermore, no significant difference was found in the levels of PCK in mathematics among pre-service teachers based on the universities they attended. This situation may stem from the similar nature of the content of mathematics education courses in preschool teacher education undergraduate programs at universities, the predominantly theoretical nature of the courses, and the lack of an integrated approach to presenting content and process standards in mathematics education.

### Research and Publication Ethics Statement

The authors declare that all information in this study has been obtained and presented in accordance with academic rules and ethical conduct. Ethical approval was obtained from the the Scientific Research and Publication Ethics Committee for Social and Human Sciences at Kahramanmaraş Sütçü İmam University. (Scientific Research and Publication Ethics Committee Approval: 35869.)

### Contribution Rates of Authors to the Article

The authors declare that each author made an important contribution to every stage of the study. The four authors worked together during the analysis and reporting of the data.

### Statement of Interest

There is no conflict of interest.

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