Volume 7 Nomor 1 (2026) Pages 31–45
Hadlonah: Jurnal Pendidikan dan Pengasuhan Anak
Email Journal: jurnalhadlonahuibbc@gmail.com
Web Journal: http://journal.bungabangsacirebon.ac.id/index.php/hadlonah

Teaching Number Concepts: A Pedagogical Content Knowledge (PCK) Analysis of Pre-service Early Childhood Teachers

Ahmad Afandi[1]✉, Pascalian Hadi Pradana[2]

[1,2] Early Childhood Teacher Education Program, Faculty of Teacher Training and Education, PGRI Argopuro University Jember

Email: aafandi832@gmail.com[1]

Received: 2026-02-19; Accepted: 2026-03-09; Published: 2026-04-16

Abstract

This study presents a comprehensive analysis of the Pedagogical Content Knowledge profile of 26 Early Childhood Education pre-service teachers in teaching number concepts. This research is motivated by the urgency of mastering early mathematical literacy as a cognitive foundation for children, which is often hindered by teachers limited pedagogical competence in transforming abstract content into concrete learning. Using a qualitative case study design, data were collected through Content Representation instruments, Pedagogical and Professional-experience Repertoires, analysis of Daily Lesson Plans, and teaching simulation (microteaching) observations. The analysis was conducted on the mastery of Subject Matter Knowledge, including Gelman and Gallistel's counting principles (one-to-one correspondence, stable order, cardinality, abstraction, and order irrelevance), as well as PCK components encompassing Knowledge of Content and Students and Knowledge of Content and Teaching. The research results showed a significant PCK profile: 38.5% at the Pre-PCK level, 50% at the Growing PCK level, and only 11.5% reaching the Maturing PCK level. The main findings indicate that although the pre-service teachers possess adequate procedural knowledge regarding number sequences, there is a profound conceptual deficit in the aspects of cardinality and one-to-one correspondence. The pre-service teachers tend to design worksheet-based learning that is drill-oriented. Furthermore, the KCS ability to anticipate children's misconceptions was found to be the weakest aspect, where the pre-service teachers often failed to detect subtle counting errors in children.

Keywords: *Pedagogical Content Knowledge (PCK), Number Sense, Early Childhood Education*

INTRODUCTION

Early Childhood Education (ECE) is a fundamental stage of education that plays a crucial role in laying the foundation for a child's cognitive, social, and emotional development. One of the primary cognitive domains focused on in the Indonesian ECE curriculum as stipulated in the Minister of Education and Culture Regulation (Permendikbud) Number 137 of 2014 concerning the National Standards for ECE and Permendikbud Number 146 of 2014 concerning the 2013 ECE Curriculum is logical and symbolic thinking skills, which encompasses the introduction to number concepts (Permendikbud No 146, 2014). The concept of numbers, often referred to as number sense, is not merely the ability to memorize number sequences ("one, two, three..."), but rather an intuitive and conceptual understanding of quantity, the relationships between numbers, and basic operations, which serves as an absolute prerequisite for successful mathematical literacy at the elementary school level (Supriyanto, 2025). Numbers are an integral part of our everyday lives. For this reason, early introduction to numeracy is crucial to ensure children are well-prepared for higher educational stages. In accordance with the spirit of emancipated learning, this introduction must be conducted through engaging and enjoyable play activities (Wahyuni, 2022).

Nevertheless, practical realities reveal a substantial gap between curriculum expectations and teachers' competencies in facilitating effective mathematics learning. Early childhood educators, especially pre-service teachers at Teacher Training Institutions (LPTK), frequently encounter complex challenges when teaching math. Because mathematics is often viewed as rigid and abstract, its instruction in early childhood settings frequently succumbs to schoolification the imposition of primary school methods like drilling and worksheets onto what should be play-based learning environments (Rohmalina et al., 2020).

This was also conveyed by (Biba et al., 2024) stated that in reality, many young children still struggle to recognize numerical symbols, count basic objects meaningfully, and master number concepts concretely. This fact indicates the need for more interactive and stimulating teaching methods. The research findings (Wahyuni, 2022) also stated that in classroom numeracy literacy learning, it was found that the skill development of several students has not yet reached an optimal level. This condition is evidenced by the fact that there are still children who experience difficulties in counting activities, determining number quantities, and solving simple problems during play activities. This phenomenon is exacerbated by the finding that many pre-service teachers possess weak mathematical content knowledge and high levels of math anxiety, which subsequently impacts the quality of their pedagogical interactions with children (Yunianto et al., 2021)

Based on preliminary data and observations conducted during the microteaching sessions, a recurring pattern emerged where the majority of Early Childhood Education (ECE) students encountered a mental block when asked to simulate the teaching of number concepts. Instead of designing grounded, play-based activities, observations indicated a tendency for students to fixate on the direct introduction of numerical symbols using whiteboards or flashcards. This abstract approach to numbers serves as a major barrier for them due to two fundamental factors. First, past mathematical trauma experienced by the students during their previous education has led them to internalize mathematics as an intimidating, highly procedural subject that is solely oriented toward right-or-wrong answers. Second, the students face a literature deficit and a lack of reference materials regarding concrete teaching methods (hands-on activities). Without role

models or direct experience of how mathematics can be taught using loose parts or natural materials, they tend to reproduce the traditional teaching methods they once received.

In an effort to dissect teacher competence, the Pedagogical Content Knowledge (PCK) framework introduced by Lee Shulman (1986, 1987) serves as a highly relevant analytical lens. PCK is defined as a unique blend of content knowledge and pedagogical knowledge that distinguishes a teacher from a mere subject matter expert (Pincheira & Alsina, 2022). A mathematician may possess a deep understanding of number theory, yet lack the PCK (Pedagogical Content Knowledge) to teach the concept of 'the number five' to a 4-year-old child who has not yet grasped number conservation. Conversely, a childcare provider might excel at managing children's behavior, but without adequate mathematical content knowledge, they may fail to provide the appropriate scaffolding when a child experiences misconceptions in counting.

Research on PCK at the secondary education level has been extensively conducted and well-documented (Wicaksono & Dwipa, 2020). However, research specifically highlighting the Pedagogical Content Knowledge (PCK) of early childhood pre-service teachers in the mathematics domain, particularly concerning number concepts, remains relatively limited in Indonesia. Yet, the education period at Teacher Education Institutions (LPTK) is a critical period for forming a teacher's professional identity and competence. If misconceptions regarding how to teach mathematics are not corrected during this phase, pre-service teachers will carry flawed teaching practices into their professional careers for decades to come (Siregar, 2025).

This study conducts an in-depth analysis of the Pedagogical Content Knowledge (PCK) profiles of 26 final-year Early Childhood Education students who have completed the cognitive and mathematics development methodology course. The analytical focus is directed towards how they construct their understanding of number principles (such as one-to-one correspondence and cardinality) and how this understanding is transformed into lesson plan designs (RPPH) and simulated teaching practices. Through the analysis of these 26 subjects, this report aims to map the students Pedagogical Content Knowledge (PCK) typologies, identify blind spots in their knowledge, and formulate strategic implications for the improvement of early childhood teacher education in Indonesia.

The urgency of this research lies in three main aspects. *First*, the aspect of early learning quality. Early numeracy is a strong predictor of future academic achievement, even stronger than early reading skills (Supriyanto, 2025). Failure to instill correct number concepts at an early age can lead to persistent mathematical learning difficulties (such as dyscalculia), or at the very least, a learning gap that is difficult to close (Soendergaard & Cachaper, 2020). Consequently, ensuring that pre-service teachers develop robust PCK serves as a preventive step to secure a high-quality educational beginning for children.

Second, the aspect of teacher professionalism development. Teacher competency standards in Indonesia, as stipulated in the Teacher and Lecturer Law and its implementing regulations, require an integrated mastery of professional and pedagogical competencies (Suharto et al., 2022). PCK analysis provides empirical insight into the extent to which this integration occurs among pre-service teachers. Do they merely “know mathematics” (Content Knowledge) or “know how to teach” (Pedagogical Knowledge) in isolation, or are they already capable of integrating the two? The answer to this question is crucial for the evaluation of Teacher Education Institution (LPTK) curricula.

Third, the aspect of enriching the PCK literature in the Early Childhood Education (ECE) context. Most PCK instruments and theories have been developed for secondary school mathematics contexts (e.g., algebra, calculus). The ECE context is unique due to the pre-operational nature of children's thinking (according to Piaget) and its heavy reliance on concrete representations. This is where the primary novelty of this research lies. To capture PCK, which often remains hidden within teachers' cognition, this study goes beyond conventional written tests by adapting and implementing the Content Representation (CoRe) and Pedagogical and Professional-experience Repertoires (PaP-eRs) instruments. The specific application of the CoRe and PaP-eRs instruments within the context of early childhood education (ECE) numeracy literacy in Indonesia remains highly scarce. Through CoRe, the students conceptual understanding is mapped structurally, while PaP-eRs are utilized to capture the reflective narratives of their pedagogical actions during teaching simulations. The combination of these instruments offers a more comprehensive methodology for dissecting the intersection between Knowledge of Content and Students (KCS) and actual practices in the field. This research contributes to enriching the body of PCK theory by dissecting specific components, such as Knowledge of Content and Students (KCS), within the developmental context of children aged 4-6 years (Pincheira & Alsina, 2022).

Based on the theoretical and empirical background above, this study formulates the following specific research problems: (1) What is the Content Knowledge (CK) profile of 26 Early Childhood Education (ECE) pre-service teachers regarding number concepts, specifically the principles of one-to-one correspondence and cardinality?; (2) What are the characteristics of the pre-service teachers' Pedagogical Knowledge (PK) in designing number learning strategies as reflected in their Daily Lesson Plans (RPPH)?; (3) To what extent is the pre-service teachers' mastery of Knowledge of Content and Students (KCS) in identifying the difficulties, errors, and misconceptions of early childhood students in learning numbers?; and (4) How is the distribution of PCK levels (Pre, Growing, Maturing) among the 26 research subjects based on the integration of CK, PK, and KCS components? Meanwhile, the objectives of this study are to: (1) Comprehensively describe the depth of the ECE pre-service teachers' mathematical Content Knowledge regarding number concepts; (2) Analyze the variety of pedagogical strategies and learning media selected by the pre-service teachers in teaching numbers, as well as their alignment with early childhood learning principles (DAP-Developmentally Appropriate Practice); (3) Evaluate the pre-service teachers' sensitivity and accuracy in diagnosing children's learning difficulties (Knowledge of Content and Students) through case simulations; and (4) Map the pre-service teachers' PCK profiles into a developmental taxonomy (Pre, Growing, Maturing) to provide specific recommendations for the development of teacher education curricula in Teacher Education Institutions (LPTK).

The concept of PCK was first introduced by Shulman as the 'missing paradigm' in educational research, bridging the dichotomy between subject matter mastery and general teaching skills, emphasizing that teachers require specialized knowledge on how to represent content so that it can be understood by students, as well as an understanding of what makes the material difficult or easy to learn (Marshman & Porter, 2022). In a subsequent development, Ball, Thames, and Phelps (2008) developed the Mathematical Knowledge for Teaching (MKT) model, which maps the domains of mathematics teachers' knowledge in greater detail (Pincheira & Alsina, 2022). The MKT (Mathematical Knowledge for Teaching) model divides teacher

knowledge into two broad categories: (1) Subject Matter Knowledge (SMK) Subject Matter Knowledge consists of: (a) Common Content Knowledge (CCK): Mathematical knowledge possessed by educated adults in general. In the context of numbers, this means standard calculation skills. (b) Specialized Content Knowledge (SCK): Mathematical knowledge unique to teaching. For example, understanding why the subtraction method of borrowing works, or analyzing students error patterns in calculations. (c) Horizon Content Knowledge (HCK): An understanding of how current mathematical topics relate to topics at higher grade levels. (2) Pedagogical Content Knowledge (PCK) Pedagogical Content Knowledge consists of: (a) Knowledge of Content and Students (KCS): Knowledge of how students think, what misconceptions are common, and what interests them. (b) Knowledge of Content and Teaching (KCT): Knowledge of instructional sequencing, selection of examples, and the most effective representation strategies. (c) Knowledge of Curriculum: An understanding of curriculum standards and relevant teaching materials. (Yaswinda & Gusmarni, 2022). This study adopts the Mathematical Knowledge for Teaching framework, specifically focusing on the intersection of Specialized Content Knowledge, Knowledge of Content and Students, and Knowledge of Content and Teaching within the context of teaching numbers in early childhood education.

To analyze students PCK, we must establish the 'content' standards to be mastered. In the literature of developmental psychology and early mathematics education, Gelman and Gallistel's (1978) theory of counting principles serves as the primary reference (Fadhilah & Rocmah, 2025). The five principles are: (1) One-to-One Correspondence: The principle that each object in the set being counted must be paired with exactly one unique number word. This is the mechanical foundation of the counting activity (Rahmawati & Amri, 2020). Common mistakes children make include skipping (missing an object) or double counting (counting the same object twice). (2) Stable Order: Number words must be used in a fixed and repeatable sequence (1, 2, 3, 4...). A child who has not yet mastered this principle might count in a random order, such as "1, 3, 5, 2..." (Andika et al., 2024). Cardinality: The understanding that the last number word said when counting a set of objects represents the total quantity of that set (Prayitno et al., 2023). This serves as the bridge from the process of counting to the understanding of quantity. (4) Abstraction: The principle that anything can be counted whether physical objects or abstract concepts (such as the beat of a sound or an idea) as long as they are discrete units. (5) Order Irrelevance: The principle that the order in which objects are counted (whether from left to right, right to left, or from the middle) does not change the total sum. Early Childhood Education (PG-PAUD) students must possess Specialized Content Knowledge (SCK) regarding these five principles. They must not only be able to count themselves (Common Content Knowledge/CCK), but also be able to identify which specific principle is being violated when a child makes a counting error. (Noviyanti & Suryadi, 2019).

A number of studies highlight the obstacles faced by early childhood education (ECE) teachers. Internal barriers include a lack of conceptual understanding, where teachers often equate the ability to recite numbers' with 'an understanding of number concepts (Rohmalina et al., 2020). This leads teachers to transition too quickly to teaching written symbols (Arabic numerals 1, 2, 3) before children have developed a solid understanding of quantity. External obstacles include the limited availability of media and pressure from 'scholastic' curricula driven by parents or primary schools that demand early literacy and numeracy skills (Astuti & Rasidi, 2020). As a result, instructional strategies are often reduced to monotonous worksheets, which fail to sufficiently stimulate mathematical thinking (Simatupang et al., 2023). The use of

manipulative media such as loose parts, blocks, and natural materials which should serve as the primary vehicle for mathematical learning in early childhood education, is often neglected or used merely as decoration without deep mathematical exploration.

METHODS

This study employs a qualitative approach with a collective case study design. This design was selected to allow for an in-depth analysis of the PCK phenomenon across multiple subjects (26 cases) who share similar characteristics (pre-service teachers) yet exhibit individual variations. This approach facilitates the extraction of rich data regarding the students pedagogical reasoning underlying their instructional decisions (Irawan et al., 2021).

The research subjects consisted of 26 students from the Bachelor's Program in Early Childhood Teacher Education (S1 PG-PAUD) at Universitas PGRI Argopuro Jember (UNIPAR) who were currently in their seventh semester. The selection of this subject aligns with the objectives of Universitas PGRI Argopuro Jember, which mandates the teaching of numeracy and prepares for its integration across various subjects, not just mathematics. University students must also be equipped with teaching methods that transform numeracy from an intimidating prospect into an enjoyable and easily comprehensible subject. Consequently, with thorough preparation at the university level, the teaching of numeracy from an early age can be conducted more effectively. This fosters children's confidence and independence, ultimately serving as a long-term solution to address the low literacy and numeracy skills of Indonesian students in international surveys such as PISA.

The selection criteria were as follows: (1) Prerequisite Completion: Participants must have passed Basic Concepts of Mathematics for Early Childhood, Cognitive Development, and Early Childhood Learning Strategies; (2) Practical Experience: Participants must be currently enrolled in or have completed Microteaching (PPL I) or the School Field Introduction Program (PLP); and (3) The subjects agreed to fully participate in the entire data collection process. Demographically, the subjects consisted of 24 females and 2 males, ranging in age from 21 to 23 years. For analytical purposes, the subjects were categorized into three clusters based on their Grade Point Average (GPA): the High Group (GPA > 3.50), the Medium Group (3.00 < GPA < 3.50), and the Low Group (GPA < 3.00), in order to examine the potential correlation between general academic ability and specific PCK

This study adapts established PCK instruments from the literature, tailored to the Early Childhood Education (ECE) context and number sense concepts (Aini Amalia Sari et al., 2023).

1. Content Representation (CoRe): This instrument was developed by Loughran et al. (2004) and has been adapted for mathematics (Achiam & Winslow, 2020). The CoRe is a matrix of reflective questions that asks students to elaborate on the "Big Ideas" regarding the topic of numbers. The questions include:
    a) What do you want the children to learn about the concept of numbers 1-10?
    b) Why is this concept important?
    c) What difficulties might children face?
    d) How will you teach it?
    e) How will you evaluate the children's understanding?
2. Pedagogical and Professional-experience Repertoires (PaP-eRs) / Vignettes: Subjects are presented with a brief narrative (vignette) depicting a classroom scenario where a child

makes a mathematical error (for example, a child counts five objects but states "six" as the total). Students are asked to analyze the error and formulate an appropriate teaching response. This instrument is designed to measure Knowledge of Content and Students (KCS) and Knowledge of Content and Teaching (KCT) in a situational context (McCray & Qi Chen, 2022).

3. Document Analysis (Daily Lesson Plan/RPPH)
   The researcher collected and analyzed the Daily Lesson Plan (RPPH) developed by the subjects for their teaching simulations. The analysis focused on the alignment between learning objectives, instructional materials, methods, media, and evaluation techniques.
4. Teaching Simulation Observation (Microteaching)
   Each subject conducted a 15-20 minutes teaching simulation focusing on number concepts. The researcher utilized an observation checklist covering several key indicators: Conceptual Clarity: How clearly the mathematical concepts were explained, Use of Concrete Media: The effectiveness of using physical manipulatives, Teacher-Child Interaction: The quality of engagement during the lesson, Response Management: How the subject handled and addressed the children's responses. (Putri, 2018).

Data was analyzed using the interactive model by Miles, Huberman, and Saldana, which includes:

1. Data Condensation: Reducing raw data from CoRe (Content Representation), vignette transcripts, and observation notes.
2. Data Display: Organizing data into subject profile matrices and frequency distribution tables.
3. Conclusion Drawing/Verification: Determining the PCK (Pedagogical Content Knowledge) level of each subject based on the following criteria:
   a) Pre-PCK: Content and pedagogical knowledge are disconnected; focus is on rote procedures; minimal anticipation of student responses.
   b) Growing PCK: Beginning to integrate content and pedagogy; aware of student difficulties, but handling strategies remain limited.
   c) Maturing PCK: Strong integration; strategies are flexible and student-centered; deep understanding of the root causes of student difficulties. (Wicaksono & Dwipa, 2020).

RESULT AND DISCUSSION

This section presents the empirical findings derived from an analysis of 26 subjects (coded S1 through S26). The research results are presented as follows.

Content Knowledge (CK) Profile: Depth of Understanding of Number Concepts

Diagnostic Tests and the CoRe (Content Representation) instrument help map the depth of Content Knowledge (CK). Rather than merely testing whether students can perform calculations, CoRe compels them to articulate the "big ideas" behind a particular concept. This instrument effectively distinguishes students who possess only a procedural understanding (focusing on written symbols or numbers) from those with a mature conceptual understanding (focusing on the essence of quantity and mathematical logic).

Analysis of the CoRe responses and diagnostic tests reveals that the majority of students possess an understanding that is more procedural rather than conceptual. Although all subjects

are able to calculate fluently (possessing Common Content Knowledge), their understanding of the mathematical structure behind numbers (Specialized Content Knowledge) varies.

Table 1. Distribution of Understanding of Number Concepts

Content Knowledge Aspect	Comprehension Indicator	Frequency (n=26)	Percentage
Defining Numbers	Representing a number as a symbol (written digit)	17	65.4%
	Representing a number as a quantity (amount)	9	34.6%
Cardinality Principle	Able to explain cardinality accurately	7	26.9%
	Confused / Does not mention cardinality (only focuses on the sequence)	19	73.1%
Correspondence Principle	Explains the importance of point-and-say synchronization	11	42.3%
	Only focuses on reciting the correct sequence of numbers	15	57.7%
Conservation of Number	Understands that the physical arrangement of objects does not change the total quantity	6	23.1%
	Does not recognize this principle as part of the teaching material	20	76.9%

The data in Table 1 reveal a concerning finding. As many as 73.1% of the subjects (19 students) did not explicitly realize the importance of the cardinality principle. In the CoRe, when asked, “What is the big idea of teaching the number 5?”, the dominant responses were “So that children can write the number 5” or “So that children know that the shape of the number 5 is like a clown.” Only a small minority (S23, S25, S12, S14, S8, S9, S26) answered, “So that children understand that a collection of 5 objects has a quantity of five, regardless of the type of objects.” This finding indicates that the Content Knowledge of early childhood education (PG-PAUD) preservice teachers is still dominated by the perception of numbers as symbolic-graphic entities (writing numbers), rather than logical-mathematical entities (counting quantities). This aligns with findings in the literature stating that teachers often get trapped in the “surface” aspects of mathematics.

Pedagogical Knowledge (PK) Profile: Instructional Strategies and Media

The analysis of Daily Lesson Plan (RPPH) documents and microteaching observations provides an overview of how this content knowledge is transformed into practice. This instrument reveals the teaching biases of pre-service teachers, demonstrating whether they genuinely facilitate children's knowledge construction through concrete materials, or if they remain trapped in traditional methods (drills and worksheets) as a result of their past educational experiences (the apprenticeship of observation).

a. Dominant Learning Strategy

Three main strategy patterns used by the 26 subjects were identified:

1) Drill & Worksheet Pattern (14 Subjects - 53.8%): This strategy is the most dominant. The subjects (such as S1-S7, S15-S20) start the learning process by singing briefly, then

immediately hand out Student Worksheets (LKA). The core activity consists of tracing dotted lines to form numbers or connecting pictures with numbers. In the PaP-eRs vignette, subjects in this group tend to suggest "Children need to practice writing numbers repeatedly to memorize them" as a solution to learning difficulties. This approach reflects weak PCK (Pedagogical Content Knowledge) because it does not align with the learning characteristics of early childhood, which require concrete experiences.

2) Teacher Demonstration Pattern (8 Subjects - 30.8%): Subjects in this group use concrete media (fruits, balls, ice cream sticks), but their use remains teacher-centered. The teacher holds the objects and counts in front of the class, while the children only watch or imitate in chorus. The interaction is strictly one-way. Although this is better than simply relying on worksheets, this strategy has not yet facilitated the independent construction of knowledge by the children.
3) Constructivist Exploration Pattern (4 Subjects - 15.4%): Only a few subjects (specifically S23, S24, S25, S26) designed activity-based (hands-on) learning. For example, S23 designed a "Fruit Market" activity where children role-play as sellers and buyers who must count the number of fruits according to an order. S25 used loose parts media (shells, stones, twigs) and asked the children to create number patterns. This strategy reflects a mature integration of PK and CK (Maturing PCK).

b. The Use of Media: The following table summarizes the types of media used in the teaching simulation.

Table 2. The Use of Instructional Media in the Simulation

Type of Media	Description	Number of Users	Application Example
Worksheets (LKA)	Paper with number/picture patterns	22	Tracing numbers, drawing lines. (Very dominant; even users of other media still use worksheets at the end)
Number Flashcards	Number picture cards	15	Drilling number names quickly
Manipulatives	Blocks, pom-poms, buttons	10	Counting quantities and putting them into containers
Natural Materials (Nature)	Leaves, stones (or rocks), shells (or seashells)	4	Ordering by size, counting, and forming number shapes
Digital Media	YouTube videos, PPT (PowerPoint)	6	Watching counting song videos like "Baby Shark" or similar ones

The high usage of LKA (22 out of 26 subjects) indicates a reliance on administrative-academic tools, which may be influenced by the 'school' culture they observed during their teaching practicum (PPL) or their own childhood experiences (apprenticeship of observation).

Profile of Knowledge of Content and Students (KCS): Diagnosis of Learning Difficulties

In this context, Vignette PaP-eRs (Simulation Cases) serve as a window into Knowledge of Content and Students (KCS). By presenting real case studies of a child's incorrect responses,

this instrument tests the students diagnostic acuity. From this, it can be analyzed whether the students respond to the child's errors reactively (blaming the child for a lack of focus) or analytically (identifying a gap in understanding regarding the cardinality principle).

The KCS component is measured primarily through vignette instruments and spontaneous responses during microteaching.

Vignette Case:

"A child is asked to take 5 blocks. They take them one by one while counting: 'one, two, three, four, five'. However, when asked, 'So, how many blocks are in your hands?', the child starts counting again from one: 'one, two, three, four, five'. What is your analysis of this situation?"

Analysis of Subject Responses:

1) Type A Response (Teacher Misconception): 16 subjects answered that the child "forgot," "lacked focus," or "had not memorized the last number." They failed to recognize that this is an indicator of an unmastered cardinality principle. The solution offered: "Telling the child to count again louder." This indicates low KCS (Knowledge of Content and Students).
2) Type B Response (Partial): 7 subjects recognized there was a comprehension issue, but could not name the concept. Answer: "The child does not yet understand that the number 5 represents the total amount."
3) Type C Response (Accurate): 3 subjects (S12, S23, S25) specifically mentioned the cardinality issue. The solution offered: "Repeating the count and emphasizing intonation on the last number, then concluding 'so there are five in total'." This is evidence of strong Specialized Content Knowledge (SCK) and KCS.

In general, KCS is the weakest domain. Students tend to assess the child's ability solely based on the final result (right/wrong) rather than observing their thought process.

Classification of Pre-Service Teachers' PCK Levels

Based on the synthesis of all instruments, the following is the mapping of the PCK levels for the 26 research subjects. The findings of this study confirm the hypothesis that early childhood pre-service teachers are still in a transitional phase between layperson knowledge and professional knowledge. The dominance of the Growing PCK (50%) and Pre-PCK (38.5%) levels indicates that teacher education has not fully succeeded in shifting the students' paradigm from learning mathematics for themselves to learning mathematics for teaching. Weaknesses in their understanding of the cardinality principle and one-to-one correspondence are highly critical.

Their abstract understanding of numbers serves as a major barrier, which is rooted in two fundamental factors. First, there is the past mathematical trauma experienced by the students during their previous levels of education, causing mathematics to be already internalized as a terrifying, procedural subject that is solely oriented towards right-or-wrong answers. Second, the students are faced with a deficit in literature and a lack of references regarding concrete teaching methods (hands-on activities). Without role models or direct experience of how mathematics can be taught using loose parts or natural materials, they tend to reproduce the traditional teaching methods they formerly received. As explained by the literature study (Fadhilah & Rocmah, 2025), These two principles are the heart of number sense. If teachers do not understand that recounting from one when asked for a total is a sign of not yet grasping

cardinality, they will continue to rely on futile counting drills instead of providing conceptual interventions (such as bundling or grouping objects to show totality). This diagnostic failure has the potential to perpetuate children's learning difficulties into elementary school.

Table 3. Summary of the PCK Levels of Early Childhood Education (PG-PAUD) Students

PCK Level	Key Characteristics	Subject	Amount	Percentage
Pre-PCK	Procedural CK; Drill/LKA dominant PK; Low KCS (blaming the child when they make a mistake); Rigid learning	S1, S2, S3, S4, S5, S6, S7, S15, S16, S17	10	38.5%
Growing PCK	CK is starting to develop (understands the concept but has difficulty explaining it); PK is varied (starts to use concrete media); KCS is starting to be empathetic but the solution is not yet sharp	S8, S9, S10, S11, S13, S18, S19, S20, S21, S22, S24, S14, S26	13	50.0%
Maturing PCK	Conceptual CK (understanding Gelman's principles); constructivist PK (child-centered); diagnostic KCS (accurate error analysis)	S12, S23, S25	3	11.5%

An interesting phenomenon was observed where several students with high GPAs (Subjects S12, S13) initially exhibited rigid teaching performances during early simulations, before eventually improving. Conversely, S25, who had a moderate GPA, demonstrated mature PCK (Pedagogical Content Knowledge) through the creative use of loose parts media. This indicates that PCK does not have a perfect linear correlation with general academic achievement; rather, it is more significantly influenced by field experience, creativity, and pedagogical reflection. The massive use of children's worksheets or LKA (53.8% dominance) emerged as a critical point of concern. Although worksheets are easy to prepare and manage, their excessive use violates the principles of Developmentally Appropriate Practice (DAP). Worksheets restrict children's exploration to static, two-dimensional representations. Research (Rohmalina et al., 2020) and (Rohmalina & Komala, 2019) This supports the finding that open-

ended and play-based approaches are significantly more effective in enhancing number concepts compared to worksheet-based approaches. The students appear to rely on worksheets as a 'comfort zone' due to a limited repertoire of alternative teaching strategies.

The Knowledge of Content and Students (KCS) component is identified as the weakest point. Early Childhood Education (ECE) students tend to have unrealistic expectations of children, e.g., expecting a 4-year-old to write numbers neatly or conversely underestimate children's logical abilities. In vignette simulations, the inability to detect counting errors (such as double counting) demonstrates a lack of clinical observation skills. This may be attributed to the limited proportion of coursework that teaches micro-observation techniques for children's mathematical behavior. Most learning evaluation courses focus more on general developmental checklist instruments rather than specific cognitive analyses (Yunianto et al., 2021). A comparison with an international study (Quilang, 2023) reveals a similar pattern, where pre-service teachers in various countries also experience difficulties in the KCS domain. However, a study in Chile indicates that specific interventions in the form of instructional video analysis can significantly improve KCS. This serves as a valuable insight for improving university instructional methods in Indonesia (Muhlisin & Lestari, 2023).

The findings regarding the Pedagogical Content Knowledge (PCK) profile of these Early Childhood Education students raise a warning alarm regarding their readiness to implement the Merdeka Curriculum, particularly concerning the Learning Outcomes (CP) element of Basic Literacy and STEAM (Science, Technology, Engineering, Arts, and Mathematics). The Merdeka Curriculum demands early childhood learning that is holistic, play-based, exploratory, and child-centered (encouraging basic inquiry and problem-solving skills). Here is an analysis of their readiness based on the PCK profile findings: (1) The paradigm clash between Children's Worksheets (LKA) and STEAM Exploration specifically the high dominance of Drill & Worksheet strategies (53.8%) and the use of LKA (22 out of 26 subjects) strongly contradicts the spirit of STEAM within the Merdeka Curriculum. STEAM requires children to explore using concrete objects, observe, ask questions, and experiment, such as the utilization of loose parts by subjects at the Maturing PCK level. Reliance on LKA for tracing numbers will stifle children's critical reasoning skills and reduce mathematics (the 'M' in STEAM) to a mere mechanical fine motor activity; (2) Diagnostic Failures and Numeracy Barriers, The Basic Literacy and STEAM elements aim to build number sense and logical reasoning, rather than just the memorization of symbols.

The fact that 73.1% of university students are unaware of the cardinality principle (a weak KCS indicator) demonstrates that they are not yet prepared to conduct proper formative assessments. Under the Merdeka Curriculum, teachers are required to implement *teaching at the right level*. If pre-service teachers cannot diagnose the root cause of an issue such as a child who constantly recounts from the beginning they will be unable to provide the scaffolding intervention the child needs to achieve the basic Literacy and Numeracy Learning Outcomes (CP); (3) The Challenge of Preparing Future Teachers, Given that only 11.5% of the subjects at the Maturing PCK level are capable of integrating mathematical conceptual understanding with center-based or role-playing activity strategies, it can be concluded that the majority of pre-service teachers at the Pre-PCK and Growing PCK levels still have the potential to "drag" the rigid paradigm of the old curriculum into the flexible Merdeka Curriculum. They will tend

to interpret the freedom offered by Merdeka Curriculum artificially. For example, they might use natural media, but ultimately still require children to complete drill-based worksheets.

CONCLUSION

Based on the data analysis conducted, the findings are as follows: (1) The Content Knowledge (CK) profile indicates that the students content understanding remains fragmented. Most comprehend numbers symbolically (written numbers) but lack an understanding of the underlying logical structures (cardinality, invariance); (2) The Pedagogical Knowledge (PK) profile shows that the designed instructional strategies tend to be conventional, dominated by drill methods and the use of children's worksheets (LKA). Only a small fraction of the subjects were capable of employing inquiry-based learning using concrete media; (3) The Knowledge of Content and Students (KCS) profile reveals that the ability to diagnose children's learning difficulties is still low. Responses to children's errors tend to be directly corrective rather than facilitative; and (4) Regarding the Pedagogical Content Knowledge (PCK) level, the majority of the students (88.5%) are at the Pre-PCK and Growing PCK levels. These diagnostic findings recommend that Teacher Education Institutions (LPTK) reconstruct their courses to shift away from worksheet-centered instruction, moving towards inquiry pedagogy, the use of concrete objects, and intensive training in scaffolding techniques

To improve the quality of Early Childhood Education graduates, the following strategic steps are recommended: (1) Revitalization of the Teacher Education Institute (LPTK) Curriculum, The focus of the "Basic Concepts of Early Childhood Mathematics" course must be shifted from mastering school mathematics content to analyzing the developmental psychology of mathematics; (2) Stronger Integration, There is a need for stronger integration between the "Basic Concepts of Mathematics" and "Early Childhood Learning Strategies" courses to maximally develop students Pedagogical Content Knowledge (PCK); (3) Strengthening Clinical Experience, Lecture methods must increase the use of video case studies (Video-Based Reflection) displaying authentic mathematical behaviors of children to train students sensitivity regarding Knowledge of Content and Students (KCS); (4) Diversification of Pedagogical Repertoire: Workshops on creating educational play tools (APE) based on loose parts and natural materials must be intensified to reduce reliance on student worksheets (LKA); (5) PCK Assessment Instruments: LPTKs need to develop performance assessment instruments (such as CoRe and PaP-eRs) as a prerequisite for passing the microteaching course, to ensure that students can not only teach in a general sense but also possess subject-specific PCK.

REFERENCES

Achiam, M., & Winslow, C. (2020). *Educational design in math and science: The collective aspect*. https://www.ind.ku.dk/english/course_overview/PhD_Courses/collective/

Aini Amalia Sari, N., Azka, R., Iqna Hibatallah, M., Studi Pendidikan Matematika, P., & Islam Negeri Sunan Kalijaga Yogyakarta, U. (2023). Analisis Kompetensi Pedagogik Calon Guru Matematika Melalui Implementasi Lesson Study Dalam PLP. *Journal in Mathematics Education, 3(2), 63-69, https://doi.org/10.14421/polynom.2023.32.63-69*

Andika, W. D., Utami, F., Alrefi, A., Sumarni, S., Siregar, R. R., Sari, R. C., & Hasan, N. I. (2024). Exploring Early Childhood Counting Principles. In *Proceedings of the 7th International Conference on Learning Innovation and Quality Education (ICLIQE 2023)*

(pp. 272–290). Advances in Social Science, Education and Humanities Research. https://doi.org/10.2991/978-2-38476-301-6_26

Astuti, F. P., & Rasidi. (2020). Persepsi Guru Tentang standar Pembelajaran Matematika Di Tk Di Kabupaten Magelang. *Jurnal Penelitian Dalam Bidang Pendidikan Anak Usia Dini (PAUDIA)*, *9*(1), 111–125. https://doi.org/https://doi.org/10.26877/paudia.v9i1.6233

Biba, L., Ngura, E. T., & Laksana, D. N. L. (2024). Analisis Kemampuan Literasi dan Numerasi Dasar Anak Usia Dini di Paud Boasiko. *Jurnal Citra Pendidikan Anak*, *3*(3), 1122–1133. https://doi.org/10.38048/jcpa.v3i3.3231

Fadhilah, P. R. N., & Rocmah, L. I. (2025). Worm Pick Media Increases Early Childhood Numeracy Achievement. *Academia Open*, *10*(1). https://doi.org/10.21070/acopen.10.2025.12774

Irawan, Y., Purnamasari, I., Asfifah, R. M., Karami, Y., & Alfiah, S. (2021). Analisis Kompetensi Pedagogical Content Knowledge Mahasiswa Calon Guru Matematika. *Himpunan: Jurnal Ilmiah Mahasiswa Pendidikan Matematika, 1 (1), 63-76.*

Marshman, M., & Porter, G. (2022). Pre-service Teachers' Pedagogical Content Knowledge: Implications for Teaching. *Proceedings of the 36th Annual Conference of the Mathematics Education Research Group of Australasia, 474-481, https://files.eric.ed.gov/fulltext/ED572978.pdf*

McCray, J. S., & Qi Chen, J. (2022). Pedagogical Content Knowledge for Preschool Mathematics: Construct Validity of a New Teacher Interview. *Journal of Research in Childhood Education*, *1*(26), 291–307. https://doi.org/10.1080/02568543.2012.685123

Muhlisin, & Lestari, K. (2023). *Penerapan Konsep Matematika Pada Anak Usia Dini*. https://doi.org/https://doi.org/10.46368/mkjpaud.v3i2.1933

Noviyanti, M., & Suryadi, D. (2019). Conceptualizing mathematical knowledge for teaching of Indonesian teacher in teaching number sense to early childhood. *Journal of Physics: Conference Series*, *1157*(3). https://doi.org/10.1088/1742-6596/1157/3/032121

Permendikbud No 146. (2014). *Peraturan Menteri Pendidikan Dan Kebudayaan Republik Indonesia*.

Pincheira, N., & Alsina, Á. (2022). Mathematical Knowledge of Pre-Service Early Childhood and Primary Education Teachers: An Approach Based on the Design of Tasks Involving Patterns. *Australian Journal of Teacher Education*, *47*(8), 50–69. https://doi.org/10.14221/ajte.2022v47n8.4

Prayitno, L. L., Mutianingsih, N., & Insani, A. (2023). Membangun Number Sense pada Anak TK A berdasarkan sudut pandang Semantik. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *7*(6), 7525–7536. https://doi.org/10.31004/obsesi.v7i6.4460

Putri, A. D. (2018). Profil Kompetensi Pedagogik Calon Guru Matematika Melalui Lesson Study Pada Mata Kuliah Micro Teaching. *Jurnal Pendidikan Matematika RAFA*, *4*(1), 1–8. https://doi.org/2460-8726

Quilang, L. J. L. (2023). Pedagogical Content Knowledge of Pre-Service Mathematics Teachers Leading to Continual Improvement. *Journal for Educators, Teachers and Trainers*, *14*(5). https://doi.org/10.47750/jett.2023.14.05.015

Rahmawati, M. S., & Amri, I. (2020). The Role of Parents at Mathematics Learning Innovation in Early Education. *Indonesian Journal of Early Childhood Education Studies*, *9*(1), 40–47. https://doi.org/10.15294/ijeces.v9i1.38349

Rohmalina, & Komala. (2019). Meningkatkan Kemampuan Pemahaman Konsep Bilangan Anak Usia Dini Kelompok B Melalui Metode Open Ended. *Jurnal Tunas Siliwangi, 105-110.*

Rohmalina, R., Aprianti, E., & Lestari, R. H. (2020). Pendekatan Open-Ended dalam Mempengaruhi Kemampuan Mengenal Konsep Bilangan Anak Usia Dini. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *5*(2), 1409–1418. https://doi.org/10.31004/obsesi.v5i2.805

Simatupang, N. D., Sholichah, S. A., & Simanjuntak, I. A. (2023). Introduction to Counting Symbols in Early Childhood with Stick Math (STIKMA) Educational Tool Games. *JPUD - Jurnal Pendidikan Usia Dini*, *17*(2), 297–311. https://doi.org/10.21009/jpud.172.08

Siregar, T. (2025). *Examining the Dimensions of Mathematical Knowledge for Teaching among Preservice Elementary Teachers*. https://doi.org/10.20944/preprints202510.1765.v1

Soendergaard, B. D., & Cachaper, C. (2020). Teaching mathematics effectively to primary students in developing countries: Insights from neuroscience and psychology of mathematics. *Global Partnership for Education, 1-62*, https://doi.org/10.1596/28116

Suharto, D., Nurdin, E. S., & Waluya, B. (2022). Pengembangan Kompetensi Pedagogical Content Knowledge pada Mahasiswa Calon Guru dalam Kegiatan Magang Bersertifikat Kampus Merdeka di Global Islamic Boarding School Yayasan Hasnur Centre. *Jurnal Penelitian Pendidikan*, *22*(2), 182–197. https://doi.org/10.17509/jpp.v22i2.50036

Supriyanto. (2025). *Urgensi Pengenalan Literasi Numerasi pada Anak Usia Dini: Dampak terhadap Kemampuan Matematika di SD dan Kesiapan Sekolah*. https://doi.org/https://doi.org/10.51675/alzam.v5i1.1093

Wahyuni, I. (2022). Analisis Kemampuan Literasi Numerasi Berdasarkan Gaya Belajar pada Anak Usia Dini. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *6*(6), 5840–5849. https://doi.org/10.31004/obsesi.v6i6.3202

Wicaksono, B., & Dwipa, N. M. S. (2020). PCK (Pedagogical Content Knowledge) profile of mathematics education students at Universitas PGRI Yogyakarta. *Journal of Physics: Conference Series*, *1538*(1). https://doi.org/10.1088/1742-6596/1538/1/012108

Yaswinda, & Gusmarni. (2022). Analisis Permendikbud Nomor 137 Dan 146 Dalam Pembelajaran Paud. *Jurnal Ilmiah PTK PNF*, *17*(2), 70–76. https://doi.org/doi.org/10.21009/JIV.1702.8

Yunianto, W., Indra Prahmana, R. C., & Crisan, C. (2021). Indonesian mathematics teachers' knowledge of content and students of area and perimeter of rectangle. *Journal on Mathematics Education*, *12*(2), 223–238. https://doi.org/10.22342/JME.12.2.13537.223-238