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Investigation of Content Validity and Exploratory Factor Analysis of Students' Pedagogical Knowledge of Science

Original research article

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Abstract

This study aims to enhance the pedagogical knowledge of science among pre-service teachers in Elementary School Teacher Education (ESTE) and identify the factors influencing their understanding of scientific concepts. We employed Cohen's Kappa coefficient to assess inter-rater reliability for the evaluation tools, alongside exploratory factor analysis (EFA) to uncover latent constructs related to Pedagogical Knowledge of Science (PKS) with a sample size of 989 pre-service science teachers in Elementary School Teacher Education (ESTE). questionnaire is designed to measure various dimensions of their pedagogical content knowledge. The findings indicate that Cohen's Kappa coefficient demonstrated strong reliability at 0.8 across multiple items in the assessment tool, suggesting consistent agreement between raters. Furthermore, exploratory factor analysis (EFA) revealed an excellent model fit. PKS has 3 domains, namely Pedagogy of Science Curriculum (PoSC), Pedagogy of Science Instructional Strategies (PoSIS), and Pedagogy of Learner and Learning (PoLL). These results underscore the importance of reliable assessment tools in evaluating teacher competencies in science education. The identified factors can inform curriculum development for teacher preparation programs by emphasizing areas where future educators may require additional support or training, ultimately enhancing educational outcomes in science classrooms.

Keywords: *Pedagogy knowledge of science; science education; pedagogy competency; exploratory factor analysis; pre-service teacher*

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Teacher education, particularly in science, plays a crucial role in shaping students' scientific understanding at the elementary-school level (Hamlen Mansour et al., 2023). As expectations for the quality of education increase, it is important to examine how pre-service teachers' backgrounds and experiences influence their ability to teach science effectively (Bastian et al., 2022). Teaching quality is determined not only by content knowledge but also by educators' pedagogical skills (Kramer et al., 2021; Ning et al., 2024). Pre-service teachers have diverse educational backgrounds and life experiences. Research shows that these factors can influence how they understand information and the teaching approaches they employ (Bastian et al., 2022; Lutovac et al., 2024; Mustafaa, 2023). In the context of science learning, understanding scientific concepts is highly dependent on pre-service teachers' ability to integrate content knowledge with appropriate pedagogical strategies (Blonder et al., 2024).

Therefore, professional development for pre-service teachers is crucial to ensure that they are ready to face challenges in the teaching and learning process. Although the role of teachers in elementary schools is very important, not only as educators but also as social and emotional caregivers of students, there is still a significant gap between the theoretical knowledge and practical skills of pre-service teachers (Elmi, 2020; Miller, 2021). This gap is clearly seen in pre-service elementary school teachers who often have difficulty applying pedagogical theories to real practices when teaching science materials (Blonder et al., 2024).

This poses significant challenges for the education system as the inability to effectively convey scientific concepts can negatively impact student understanding (Schlopsna & Scheersoi, 2024). Previous research has noted contradictions in the teacher role regarding the integration of learning into classroom planning (Chung et al., 2024; Porta & Todd, 2024), and teacher recruitment is inadequately prepared to teach (Hamlen Mansour et al., 2023).

However, there is a lack of in-depth research on the specific challenges faced by pre-service elementary school teachers in Indonesia when trying to apply pedagogical theories, particularly in relation to science pedagogical competency.

This study seeks to address this gap by offering fresh insights into how students can be better equipped to handle classroom realities. Previous research has indicated that many elementary schools in Indonesia grapple with significant issues, such as a shortage of qualified teachers and a lack of ongoing professional development for educators (Elmi, 2020). Empirical evidence suggests that although higher education curricula are designed to enhance the academic competence of pre-service science teachers, their implementation often fails to align with practical needs in the field (Othman et al., 2024). This raises critical questions about the effectiveness of current training programs and underscores the need for systematic reforms to meet contemporary demands.

In Indonesia, studies have focused on improving science pedagogical competence, but only on theoretical aspects without providing valid instruments to measure teachers' science pedagogy. Previous studies often did not consider local context and student needs as components of science pedagogy. To address this issue, researchers have developed and validated instruments to assess pre-service primary school teachers' science pedagogy, addressing the need for brevity in educational contexts (Weyers et al., 2024). Valid and reliable instruments will certainly provide a clear picture of the level of mastery of science pedagogy of pre-service teachers to meet their needs for effective science teaching, as well as help them identify areas that need to be improved. With the right instrument, science education lecture programs in universities can be adjusted to meet the specific needs of pre-service teachers, so that they can improve science education at the elementary level.

Literature Review

The Role and Characteristic of Pre-service Teachers in Indonesia

In Indonesia, pre-service teachers preparing to become primary school educators must teach multiple subjects like civic education, mathematics, science, Bahasa Indonesia, and social studies. This role requires broad subject knowledge and effective teaching methods for young learners (Istenic et al., 2023; Orakova et al., 2024). This situation highlights a critical concern regarding the adequacy of our teacher preparation programs in equipping future educators to manage their diverse responsibilities (Blonder et al., 2024; Val & López-Bueno, 2024). While comprehensive subject knowledge is essential, it frequently remains superficial and does not adequately prepare teachers for the complexities of classroom dynamics and student engagement (Silva-Díaz et al., 2023; Zhang & Zhang, 2020).

Pre-service teachers are expected to gain a basic understanding across multiple disciplines (Fernández et al., 2023), yet many enter classrooms without deep expertise in any particular area. This lack of depth can lead to student disengagement, as they seek meaningful and relevant learning experiences (Müller et al., 2021). The challenge is not only in acquiring knowledge but also in developing the ability to connect concepts in a meaningful way (López et al., 2023; Portuguez Castro & Gómez Zermeño, 2020) — a skill that is often underemphasized in traditional teacher training programs.

Additionally, as they adopt developmentally appropriate practices, pre-service teachers must deeply understand child development theories to create supportive learning environments where students feel safe and motivated (Liu et al., 2023). However, the effectiveness of these theories in practice is often limited. Many educators face significant challenges in implementation due to systemic constraints and a lack of adequate support from educational institutions (Mohammed et al., 2024; Mpu & Adu, 2021). This gap between theory and practice raises concerns about the extent to which current educational paradigms genuinely prepare teachers for the complexities and challenges they encounter in real-world settings.

Pedagogical Knowledge of Science (PKS) Factor

Pedagogical competence is a crucial aspect of education that has been developed across various disciplines, including science teaching (Habiyaremye et al., 2023; Ranta et al., 2023; Shulman, 1987). Teachers require a deep understanding of teaching materials to effectively assist students in grasping the learning content (Ning et al., 2024).

Comprehending how students learn and engage with scientific concepts is essential for enhancing the quality of science education (Viehmann et al., 2024). Despite research indicating that science teachers should integrate material with other disciplines (Naumescu, 2008), there remains a gap in understanding how students perceive science learning concepts, which presents challenges in crafting effective teaching strategies for them.

According to Ball et al. (2008), teachers require four domains of Mathematical Knowledge for Teaching (MKT), which are equally applicable to science education, as follows: These domains encompass knowledge of the teaching material, the specific content students need to learn, the connection between this knowledge and teaching methods, and interactions with students. This indicates that efforts to enhance educational quality will be hindered without a profound understanding of how students grasp scientific concepts. While Magnusson et al. (1999) highlighted the significance of pedagogical content knowledge —including curriculum, student understanding, teaching strategies, and assessment — there is a noticeable lack of studies focusing on how preservice teachers develop skills in comprehending students' learning processes in science.

In Indonesia, many pre-service teachers have limited access to quality training in science pedagogy. Higher education institutions' inadequate support compounds this issue, as training programs do not fully prepare teachers to explain scientific concepts to students from diverse backgrounds. Greater attention to pedagogical aspects in teacher preparation is needed to effectively meet students' learning needs (Macken et al., 2020; Saadaldin et al., 2022).

Therefore, in this study, especially in the development of science pedagogical competence, the researcher used the term Pedagogical Knowledge of Science (PKS). In the Pedagogical Knowledge of Science that must be possessed by PGSD students to teach science in elementary schools, it will be developed based on 3 domains, namely Pedagogy of Science Curriculum (PoSC), Pedagogy of Science Instructional Strategies (PoSIS), and Pedagogy of Learner and Learning (PoLL). To have these competency standards, students construct their learning experiences to obtain Pedagogical Knowledge of Science as a whole. When pre-service teachers already have professionalism in teaching, the level of self-confidence and efficacy when teaching will increase, which will have a significant effect on obtaining active classes and high-achieving students (Miller, 2021). Several studies have shown that students gain more knowledge when teachers explicitly tell them about the objectives of the lesson.

Methods

This study provides two phases of data analysis, including content validity by expertise and exploratory factor analysis using a statistical approach. The research procedures are as follows.

Content Validity

This study aimed to measure the pedagogical knowledge of science among pre-service elementary school teachers. The researcher used Cohen's Kappa to assess the reliability between raters through expert judgment (Casagrande et al., 2020). The interpretation of kappa values can vary, but in general, values between 0.41-0.60 are considered moderate agreement, 0.61-0.80 as substantial agreement, and above 0.80 as almost perfect agreement (Tago et al., 2021). In this assessment, the rater will assess the reliability of the pedagogical knowledge of science (PKS) questions of pre-service elementary school teachers. Furthermore, Vakili & Jahangiri (2018) stated that the expert panel consisted of three (3) to eight (7) people who were experts in the fields of pedagogy and professional development. In detail, there are several stages of reliability and content validity estimation in Cohen's Kappa, namely (1) developing instruments, (2) providing validation forms, (3) selecting expert review panels, (4) conducting content validation, (5) providing item scores and interpreting results.

Phase 1. Developing Instrument

The initial phase of developing the research instrument involved drafting questions. Preliminary questions related to PKS were formulated based on pertinent theories and a review of several relevant articles concerning the construction of PKS questions. The design of the questions in this study adhered to several constructs proposed by experts who asserted that... Furthermore, the design of multiple-choice questions (MCQ) was guided by criteria emphasising the alignment of content with learning objectives, consideration of cognitive levels in question formulation, and attention to question structure (Liu et al., 2024; Naidoo, 2023). Nonetheless, rigorous evaluation by experts is crucial to ensure the quality and validity of multiple-choice questions, irrespective of the method employed for their creation (E et al., 2023). Additionally, the criteria stipulate that the items prepared must be concise, clear, simple, and easy to understand, avoiding ambiguity (Zikmund et al., 2013).

Phase 2. Providing a Validation Form

The content validation instrument was provided to obtain the same agreement and perception between expert judgment, researchers, and the objectives of this study. The content validity form was provided to ensure the same perception between the expert panel, authors, and research objectives. This is important to ensure that the instrument can be understood to estimate the relevance and representation of the targeted construct. The researcher created a validation sheet for content validity, which was used by the expert panel. In addition to the assessment guidelines, there are 3 indicators assessed in the PKS, namely Pedagogy of Science Curriculum (PoSC), Pedagogy of Science Instructional Strategies (PoSIS), and Pedagogy of Learner and Learning (PoLL). The instrument to measure the PKS of pre-service elementary school teachers was developed by the researcher himself by adapting from several research (ASTA & Monash University, 2002; Ball et al., 2008; Magnusson et al., 1999; Naumescu, 2008). The PKS items and measurements are presented in Table 1.

Table 1.
Content Assesment and Criteria

PKS Aspect	PKS Indicator	Items	Number	Degree of Relevance		
				1	2	3
Pedagogy of Science Curriculum (PoSC)	Science goal and objectives	Pre-service teachers can design content for understanding science learning	4			
		Pre-service teachers design science learning objectives that are in accordance with the curriculum	7			
		Pre-service teachers analyze best practices in science learning	8			
		Pre-service teachers analyze the suitability between learning objectives and the indicators of questions that are prepared	9			
		Pre-service teachers evaluate learning objectives in achieving science learning outcomes	10			
	Areas of student difficulty	Pre-service teachers are able to analyze misconceptions in science learning	1			
		Pre-service teachers are able to develop solutions to overcome student difficulties in science learning	2			
		Pre-service teachers are able to identify science concepts that are often a source of difficulty for students	3			
	Requirement for learning	Pre-service teachers can identify relevant curriculum (learning) requirements for science learning	5			
		Pre-service teachers can apply appropriate educational resources to meet science learning requirements	6			
Pedagogy of Science Instructional Strategies	Methods of assessing science learning	Pre-service teachers can analyze activities in compiling assessment methods	11			
		Pre-service teachers can design learning assessments	13,14,16,			
		Pre-service teachers can apply appropriate portfolio assessment methods to measure science learning outcomes	18-20			
	Science-specific instructional strategies	Pre-service teachers can compile instructional designs in teaching science in the classroom	12			
		Pre-service teachers can evaluate appropriate strategies for science learning	15			
		Pre-service teachers can compile scenarios related to the contextualization of science in the real world	17			
	ICT utilization	Pre-service teachers can identify various ICT resources that can be used in science learning	21			
		Pre-service teachers can integrate ICT in science learning to enhance student engagement	22			
Pedagogy of Learner and Learning (PoLL)	Theory and student characteristic	Pre-service teachers can identify the application of learning theories in science learning	23			
		Pre-service teachers are able to analyze student characteristics that influence the learning process	25-27			
		Pre-service teachers can evaluate the application of learning theories in the context of science learning	29,31			
	Classroom management	Pre-service teachers can identify various effective classroom management strategies	24			
		Pre-service teachers can implement physical arrangements that support learning	28			
		Pre-service teachers can develop a comprehensive classroom management plan	30			

Notes. 1 (Feasible), 2 (Feasible with improvements), 3 (major improvements)

Phase 3. Selecting a review panel of expert

Content validity aims to ensure that the items used to measure a construct or variable are adequate and in accordance with the study objectives. In this study, we invited five experts from two universities in Indonesia, considering that the respondents were Indonesian students. The experts involved in this study were lecturers with a minimum of a doctoral degree and publication experience, as indicated by the Scopus profile h-index. In general, all experts involved in this content validity had experience publishing papers in the fields of pedagogy, teaching, and learning. The expert panel was selected to evaluate the instrument elements and rank them based on their relevance and representativeness of the content domain. Panel members were asked to rank the instrument items in terms of their clarity and relevance to the underlying construct study according to the theoretical definition of the construct and dimensions on a 3-point ordinal scale. Table 2 accessing student economic behavior is presented in Table 2 showing the details of expert judgment for assessing PKS.

Table 2.
Domain Expert Judgement and Experience

No	Expertise	Institution	Experience	H-index
1	Professor	Yogyakarta State University	40 years	9
2	Professor	Universitas Negeri Semarang	32 years	11
3	Professor	Yogyakarta State University	38 years	3
4	Associate professor	Yogyakarta State University	20 years	1
5	Associate professor	Yogyakarta State University	10 years	13

Notes. Source by Personal Data (2025)

Phase 4. Performing Content Validation

The implementation of this validation began with filling out the expert validator application form at the UNY Faculty of Education and Psychology. The application requirements are to attach the instrument and an instrument validation sheet. After the application is successful, the expert validator receives a notification regarding the application. If the expert validator approves, the researcher will contact the expert validator for consultation regarding the PKS instrument. In this case, experts were asked to assess the subjectivity of the instrument. The session continues with the expert panel filling out the answers on the form prepared by the researcher, and the researcher collects the form at the end of the session for further analysis. In addition, the researcher explained the survey form and comments used in the session to the expert panel. All expert panels will evaluate the appropriateness and clarity of all indicators used in the research instrument, using assessment techniques.

Phase 5. Providing the Score Items and Result Interpretation (Cohen's Kappa)

In this phase, the objective assessment of content validity used the Cohen Kappa validity index. Cohen's Kappa was used to test inter-rater reliability which aims to determine whether the data obtained are a valid and reliable representation of the measured PKS variables (McHugh, 2012). The statistical size of Cohen's kappa ranges from -1 to +1. This study used JASP as a statistical tool to measure interrater reliability. Fleiss' Kappa was used because there were more than three raters, and Krippendorff's alpha. The acceptable limit criteria are presented in Table 3.

Table 3.
Domain Expert Judgement and Experience

Value of Kappa	Level of Agreement	% Data that are Reliable
0-.20	None	0-4%
.21-.39	Minimal	4-15%
.40-.59	Weak	16-35%
.60-.79	Moderate	36-63%
.80-.90	Strong	64-81%
Above .90	Almost Perfect	82-100%

Exploratory Factor Analysis

EFA was conducted to measure the Pedagogical Knowledge of Science test variable that met the indicators of the developed construct. The proof of this EFA was conducted using the Jamovi software. EFA aims to detect latent sources of covariation in a measuring instrument to find characteristics and relationships between variables without determining the model in the data (Prasojo et al., 2020).

Data Collection

The respondents of this study were undergraduate students of Elementary School Teacher Education at two universities in Semarang, Central Java, Indonesia. The sample was selected using a simple sampling method. The criteria for participants in this study were students who were involved in the Elementary School Science Learning Development course and had taken the Basic Science Concepts course. The PKS test questions were administered to 989 participants.

Instrument Development and Measurement

This study used a complex multiple-choice question type with 31 items. These items are used to measure the Pedagogy of Science Curriculum (PoSC), Pedagogy of Science Instructional Strategies (PoSIS), and Pedagogy of Learner and Learning (PoLL). The instruments were adapted from previous studies and relevant literature reviews.

Data Analysis

EFA has five stages in its analysis protocol: 1) ensuring that the processed data are suitable for use in EFA analysis (a sample size above 500 is better); 2) how the covariance factors are extracted; 3) determining the criteria used to determine/decide the extraction factors from the EFA results; 4) choosing a rotation method (varimax/quartimax/oblimin/promax); and 5) interpretation (B. Williams et al., 2010). In EFA, we will see how many factors are formed from the processed data with the criteria of factor loading> 0.30; RMSEA <0.05; TLI, and CFI> 0.90; Bartlett's test <0.05; and KMO> 0.60.

Results and Discussion

This study examined the content validity and EFA of the PKS test questions for pre-service elementary-school teachers. The instrument for measuring student PKS was adapted from the relevant literature and preliminary studies, consisting of consumptive and productive behaviours. The expert agreement value of an item was obtained by calculating Fleis' Kappa using the JASP application. The results of Fleiss' Kappa and Krippendorff's alpha are presented in Table 4.

Table 4.
The Results of Fleiss' Kappa and Krippendorff's alpha

Method	Rating	Kappa	Rating	Fleiss' kappa	SE Fleiss' kappa	Krippendorff's alpha	SE Krippendorff's alpha
Nominal	Rater 1 – Rater 2	0,792	Overall	0,800	0,054	0,801	0,069
	Rater 1 – Rater 3	0,897	1	0,849	0,073		
	Rater 2 – Rater 3	0,896	2	0,760	0,073		
	Rater 1 – Rater 4	0,842	3	0,779	0,073		
	Rater 2 – Rater 4	0,636					
	Rater 3 – Rater 4	0,743					

Notes. 31 items and 4 raters

Table 4 presents the results of the reliability analysis using Fleiss' kappa and Krippendorff's alpha methods for nominal data, involving 31 items assessed by four raters. The overall Fleiss' kappa value of 0.800, with a standard error (SE) of 0.054, indicates a strong level of agreement with a reliability level of 80%. Rating 1 achieved the highest value (kappa = 0.849), indicating a high consistency of assessment, and that the PKS question development instrument that was prepared was feasible. Meanwhile, rating 2 and rating 3 each had kappa values of 0.760 and 0.779, respectively, with the same SE (0.073), indicating moderate to high consistency of agreement. Krippendorff's alpha for nominal data reached $\alpha = 0.801$ with an SE of 069. This indicates a strong consistency in the raters' evaluations.
The instrument to measure the PKS of ESTE students was adapted from the relevant literature and preliminary studies, consisting of three domains developed by the researcher.

The evaluation results show that the level of consistency of interrater agreement has a strong level of agreement. However, the results of interrater agreement have not reached 0.90 (almost perfect); therefore, it is necessary to make improvements to the complex multiple-choice questions that have been developed by considering several things, such as MCQs must be designed to test high-level cognitive skills, not just remembering facts (Liu et al., 2024), and avoiding item writing errors (IWFs) is very important, because this can affect student outcomes and hinder objective evaluation of their knowledge (Przymuszała et al., 2020). In conclusion, creating effective MCQs in complex settings requires a combination of subject expertise, an understanding of cognitive assessment principles, and a careful review process.

Exploratory Factor Analysis of Pedagogical Knowledge of Science

EFA was conducted to determine the strong correlation between items and included in the factor analysis. This analysis aimed to predict the dimensions necessary for assessing the PKS of pre-service elementary school teachers, as detailed in Table 5.

Table 5.
EFA for PKS Pre-service Teachers'

Factor	Number	Exploratory Factor Analysis							Reliability Test (Cronbach's Alpha)
		KMO	Bartlett's	RMSEA	SRMR	Factor Loading	CFI	TLI	
Pedagogy of Science Curriculum (PoSC)	4	0,929				0,624			0,826
	7	0,916				0,617			
	8	0,928				0,581			
	9	0,946				0,544			
	10	0,940				0,484			
	1	0,924				0,472			
	2	0,950				0,438			
	3	0,950				0,414			
	5	0,929				0,379			
	6	0,954				0,346			
Pedagogy of Science Instructional Strategies	11	0,938	< 0,001	0,032	0,028	0,511	0,944	0,930	0,815
	13	0,958				0,526			
	14	0,961				0,498			
	16	0,941				0,485			
	18	0,923				0,463			
	19	0,904				0,428			
	20	0,933				0,405			
	12	0,854				0,397			
	15	0,927				0,369			
	17	0,942				0,367			
	21	0,936				0,361			
	22	0,911				0,345			
Pedagogy of Learner and Learning (PoLL)	23	0,885				0,411			0,797
	25	0,958				0,370			
	26	0,898				0,429			
	27	0,941				0,465			
	29	0,954				0,411			
	31	0,907				0,371			
	24	0,960				0,368			
	28	0,946				0,355			
	30	0,839				0,341			
Total Average		0,936							0,889

Notes. N= 989. Participant were on average 20 years old. Analysis using JASP. Applied rotation method is varimax, parallel analysis, and correlation matrix.

Table 5 presents the results of the Exploratory Factor Analysis (EFA) for the PKS question construct. A total of 35 questions were subjected to EFA; however, four questions did not satisfy the requisite criteria, as their factor loadings were below 0.30. The EFA employed the varimax rotation method, and the findings indicated an overall Kaiser-Meyer-Olkin (KMO) measure of 0.936, signifying a very high level of sampling adequacy. This suggests that the dataset is well-suited for uncovering the underlying structure using factor analysis. Factor loadings exceeding 0.30 demonstrated a significant relationship between the variables and measured factors. The Root Mean Square Error of Approximation (RMSEA) and Standardised Root Mean Square Residual (SRMR) values below 0.05 indicated a good model fit, while the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values above 0.90 further confirmed the model fit. The overall reliability of the item construct was 0.889, reflecting a high level of reliability among the question components. This implies that the identified factor structure effectively explains the variance in the data, allowing for further analysis or interpretation of the factors based on these results.

The items of the factors were then assessed for their naming, representative terms, and ease of verbal communication (Zhao et al., 2021). The first factor is known as Pedagogical of Science Curriculum (PoSC), the second factor is known as Pedagogy of Science Instructional Strategies (PoSIS), and the third factor is known as Pedagogy of Learner and Learning (PoLL). These results reveal that high loadings indicate good parsimony and intercorrelation among the instruments. Previous research has shown that preparing pre-service elementary school teachers to teach science effectively in the classroom is a crucial component (Deehan & MacDonald, 2024; Peikos & Sofianidis, 2024), so that pre-service elementary school teachers will be better prepared to face the challenges of building the next generation by understanding the science curriculum, understanding the characteristics of student learning, and being able to apply science teaching instructional strategies (Kim et al., 2022). These findings support previous findings showing that measuring the PKS abilities of pre-service elementary school teachers using a rigorous scientific approach can provide implications for constructing a valid instrument to predict the PKS development framework of pre-service elementary school teachers.

Conclusion

This study aims to provide a new measuring instrument for pedagogical knowledge of science (PKS) of pre-service elementary school teachers using content validity and exploratory factor analysis to evaluate construct validity. Based on the analysis of the questionnaire scale, it can be concluded that content validity using Cohen's kappa shows an overall Fleiss' kappa value of 0.800 and Krippendorff's α reaches 0.801, which means that the level of agreement is strong with a reliability level of 80%. Furthermore, the EFA results show that the Pedagogical Knowledge of Science (PKS) instrument measures three factors, namely Pedagogical of Science Curriculum (PoSC), Pedagogy of Science Instructional Strategies (PoSIS), and Pedagogy of Learner and Learning (PoLL). Information collected from the PKS instrument can be used to improve the readiness and ability of pre-service elementary school teachers because this competency directly affects students' academic performance and the overall quality of education. The results of the three PKS factors analyzed using EFA include explaining that the role of mastering the Pedagogical of Science Curriculum (PoSC) is important for developing their pedagogical content knowledge (PCK) and becoming effective science educators. This will certainly lead to the second factor, namely the Pedagogy of Science Instructional Strategies (PoSIS), which will help them to organise and describe lessons more effectively. Finally, the third factor has an important role in making learning mindful, meaningful, and joyful, namely the Pedagogy of Learner and Learning (PoLL). The role of the third factor is to create significant learning experiences and become adaptive experts who can support students' desired learning.

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