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Research Article

Redefining early childhood pedagogy: Validating a digital-era competency model for innovation, creativity, and social interaction

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Education Transformation in the Industrial Revolution 4.0 era demands early-childhood teachers to possess pedagogical competencies that are not only theoretical but also innovative, creative, and contextual. These competencies are essential for supporting the holistic development of young children, encompassing cognitive, social, emotional, and motor dimensions. This study aimed to develop and validate a Pedagogical Competency Model 4.0, consisting of four main constructs: learning innovation, creativity, social interaction, and pedagogical implementation. This study employed a quantitative approach to test a theoretical model using Confirmatory Factor Analysis and group invariance testing to assess the validity and reliability of the theoretical constructs of the Early Childhood Education Teacher Competency Model 4.0. The participants were 351 teachers recruited from various schools across Indonesia. The competency model was evaluated using an instrument administered on a four-point Likert scale. The results indicated that the model exhibited excellent fit with all goodness-of-fit indices meeting acceptable thresholds. All constructs demonstrated strong convergent validity, discriminant validity, and high reliability. The novelty of this study lies in the development of a Pedagogical Competency 4.0 model that integratively combines four essential elements for early childhood education learning that are relevant in the digital era. This model can serve as both a conceptual framework and a measurement instrument for the comprehensive development and evaluation of teachers' competencies. Its practical implications include contributions to policies aimed at improving Early Childhood Education teacher quality, competency-based training programs, and the design of curricula that are responsive to the challenges of 21st-century education.

Keywords: CFA; Creativity; Early childhood; Learning innovation; Pedagogical competency 4.0; Social Interaction

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1. Introduction

Pedagogical competence essentially refers to a set of knowledge, skills, and attitudes that teachers need to design, implement, and evaluate learning effectively (Pantić & Wubbels, 2010). In the current era of digital transformation, there is a need for evolution toward a more comprehensive Pedagogical Competency 4.0. This new competency not only includes the basic abilities to design

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and evaluate learning, but also emphasizes three main pillars: (1) learning innovation through the use of cutting-edge technologies such as augmented reality and educational robotics (Papadakis et al., 2021), (2) development of creativity using art-based, STEM, and experimental-project approaches to stimulate children's inventive capacity (Burnard & Dragovic, 2015), and (3) strengthening social interaction through collaborative methods and educational social-media platforms (Marsh et al., 2016).

The Industrial Revolution 4.0 has brought about major changes across various sectors, including education. Digital transformation, automation, and the integration of artificial intelligence demand that educational systems redesign learning approaches to become more relevant to the needs of the future (Schleicher, 2020). Some experts (Luckin, 2018; Pedró et al., 2019; Selwyn, 2019; Zawacki-Richter et al., 2019) have also pointed out that digital transformation and Artificial Intelligence [AI] are key factors in education. In the context of ECE, this shift demands that teachers not only possess basic pedagogical competence but also master 21st-century skills encompassing innovation, creativity, social interaction, and adaptation to technology (Falloon, 2020). Learning innovation in ECE can be realized through the use of technologies such as digital game-based learning, educational robotics, and augmented reality [AR], which have been proven to increase children's engagement and enhance their understanding (Bers et al., 2019; Papadakis et al., 2021). The use of these tools not only makes learning more interesting but also trains children in problem-solving from an early age. In addition, children's creativity can be developed through arts and STEM (Science, Technology, Engineering, and Mathematics) based approaches, which encourage exploration and self-expression (Burnard & Dragovic, 2015; Campbell et al., 2018). Activities such as collaborative art projects or simple science experiments help children develop critical and innovative thinking.

Social interaction is also a key aspect of ECE, especially in an era where children are increasingly exposed to technology. Collaborative learning and role-playing can strengthen children's communication skills and empathy (Lillard et al., 2013; Rogoff et al., 2018). Teachers can utilize safe educational social-media platforms to train children to interact positively in the digital world (Marsh et al., 2016). Therefore, ECE teachers must master traditional pedagogical competencies and be skilled in integrating technology, stimulating creativity, and building meaningful social interactions (Falloon, 2020). The combination of these three elements ensures that ECE remains relevant in preparing children to face the challenges of the 21st century.

With the rapid development of educational technology, the current reality of early childhood teachers' pedagogical competencies shows a significant gap between the demands of the digital age and teachers' actual capacities. Recent research has revealed that most early childhood teachers still face difficulties in effectively integrating technology into learning (Nikolopoulou, 2021). A study in 15 countries by Dong and Xu found that only 32% of ECE teachers felt ready to use digital tools, while 68% admitted that they needed intensive training (Dong & Xu, 2021). This situation is exacerbated by the lack of supporting infrastructure in many ECE institutions, especially in rural areas (Lewis et al., 2024).

Another challenge is the resistance to changes in the learning paradigm. Many teachers tend to stick with traditional methods (such as one-way speeches) because of habit, lack of confidence, or administrative burdens that get in the way of trying new teaching approaches (Fleer, 2019). Longitudinal studies have shown that early childhood education programs that successfully integrate creative technology (such as simple coding or digital storytelling) demonstrate a 40% increase in children's collaboration skills (Marsh et al., 2016).

However, the demand to combine creativity and social interaction in learning is often hampered by limited resources. A report from the Organisation for Economic Co-operation and Development [OECD] highlights that early childhood teachers in developing countries have an average of only 1-2 hours per week to design creative activities due to their heavy teaching schedules (OECD, 2020). This contrasts with findings emphasizing that at least 30% of early childhood education learning time should be allocated to project-based creative play to optimize children's executive

functioning development (Whitebread et al., 2012). Interaction between teachers and students is not limited to the role of teachers; it also requires quality interaction between teachers, creativity in delivering material, and courage to innovate (Fleer, 2013; Whitebread et al., 2012). The development of the 4.0 education era has shifted the pedagogical paradigm from the mere mastery of technology to a more holistic approach. Recent research has revealed that modern pedagogical approaches must demonstrate that effective teachers in the digital age are those who can apply "high-tech, high-touch" strategies or combine digital tools with deep human interaction (Tang et al., 2023).

A pedagogical approach that is responsive to the 4.0 era not only emphasizes the use of digital technology, but also the strengthening of social-emotional aspects, collaboration, and reflective abilities in teaching (Mishra & Koehler, 2006). Therefore, the development of the Pedagogical Competency Model 4.0 is important as a new framework that encompasses four main dimensions: learning innovation, creativity, social interaction, and holistic pedagogical application. These four dimensions reflect the need to design learning that is not only oriented towards academic results but also pays attention to the meaningfulness of the learning process for children.

In the context of ECE, Hatzigianni provides empirical evidence of the importance of balancing technology and social-emotional development (Hatzigianni, 2018). The reflective aspect of digital pedagogy has also received new emphasis (Akyol, 2025; Falloon, 2020). Research in Teaching and Teacher Education has developed the concept of "Reflective Digital Pedagogy," which emphasizes the importance of critically evaluating the impact of technology on learning. Teachers not only need to be skilled in using digital tools, but also must be able to analyze their effectiveness and adapt them to the individual needs of children. This approach is crucial, given the risk that inappropriate use of technology can reduce the depth of learning.

Although existing research has proven the importance of four key competencies for ECE teachers in the Industry 4.0 era—digital pedagogy, creativity, social interaction, and reflective practice (Falloon, 2020; Tang et al., 2023) — studies testing integrated models of these four competencies are still very limited, especially in the Indonesian context. This research gap can be analyzed in several dimensions. First, there is an empirical gap due to the lack of comprehensive data showing how these competencies interact and reinforce each other in actual teaching practices (Hatzigianni, 2018). Existing studies tend to be fragmented, testing only certain aspects separately without considering the systemic interrelationships (Nikolopoulou, 2021). Second, there is a competency mapping gap because Indonesia does not yet have an ECE teacher competency framework that explicitly covers these four dimensions (OECD, 2020). Existing teacher competency standards are still too general to meet the needs of the digital age. In addition, there is an implementation gap evident in the lack of documentation on best practices for implementing this integrated model (Dong & Xu, 2021), as well as an evaluation gap due to the lack of standard assessment instruments for these combined competencies (Marsh et al., 2016). Future research should focus on developing contextualized integrated models, valid measurement instruments, and longitudinal studies of their impact (Papadakis et al., 2021), while aligning findings with national education policies to address these gaps.

This research specifically addresses four critical gaps in ECE teacher competency research. First, there is an empirical gap due to insufficient comprehensive data demonstrating how digital pedagogy, creativity, social interaction, and reflective practice interact synergistically in actual teaching contexts. Second, a competency mapping gap exists because Indonesia lacks an ECE teacher competency framework explicitly addressing these four digital-era dimensions. Third, there is an implementation gap evident in the scarcity of documented best practices for integrated competency application. Finally, an evaluation gap persists due to the absence of validated assessment instruments measuring these combined competencies holistically.

A gap exists between the competencies of certified and uncertified early childhood teachers, particularly in learning innovation, creativity, and social interaction. Other studies show that certified teachers are 45% more capable of integrating digital technologies, such as interactive

learning applications, while 72% of non-certified teachers still rely on conventional methods (Wijaya et al., 2024). In terms of creativity, certified teachers were observed to design project-based creative activities at a significantly higher rate than their non-certified colleagues (Craft, 2005). The aspect of social interaction also shows striking differences, as research has demonstrated that certified teachers possess stronger scaffolding skills and are more effective in facilitating student interactions (Van de Pol et al., 2010). These findings underscore the urgency of evidence-based competency equalization programs using appropriate instruments to minimize disparities in the quality of ECE learning in Indonesia, while emphasizing the importance of improving access to training and educational resources for all teachers.

Based on the above explanation, this study aims to develop and validate the Pedagogical Competence 4.0 model by testing the suitability between the theoretical model and the data using Confirmatory Factor Analysis [CFA], as well as testing the equivalence of the model between certified and uncertified teachers. This study is expected to provide empirical and theoretical contributions to the development of adaptive and contextual ECE teacher competencies in line with the dynamics of the 21st century.

The expected contributions of this study include: (1) providing an empirically validated, integrated competency model suitable for the Indonesian ECE context, (2) offering a reliable measurement instrument for teacher assessment and professional development, (3) informing evidence-based policy development for ECE teacher certification and training, and (4) establishing a theoretical foundation for future research on digital-era pedagogical competencies.

Existing instruments that assess teachers' pedagogical competence generally focus on conventional dimensions such as lesson planning, classroom management, and assessment skills (OECD, 2020; Pantić & Wubbels, 2010). However, these instruments are not yet adequate to capture the complexity of pedagogical practices required in the digital and creative learning environments of the 21st century. Most existing measures, including the Indonesian National Teacher Competency Standards and the PAUD National Standards, do not explicitly assess competencies such as digital learning innovation, creative pedagogy, or reflective social interaction. Therefore, there is a clear need to develop a new, contextually relevant scale that integrates technological, creative, social, and reflective elements into a single measurement framework. The Pedagogical Competence 4.0 Scale proposed in this study addresses this gap by offering an integrated construct that reflects the holistic demands of teaching in the Industry 4.0 era. This new scale differs from existing measures by combining four core dimensions learning innovation, creativity, social interaction, and pedagogical implementation into a single validated instrument designed specifically for early childhood education teachers in Indonesia.

2. Literature Review

2.1. Pedagogical Competence in the ECE Context

Pedagogical competence is an essential element of successful learning, especially in ECE. This competence includes the ability of teachers to design, implement, and evaluate learning effectively in accordance with the characteristics and developmental needs of children (Pantić & Wubbels, 2010). In the ECE context, this competency is not only cognitive-technical in nature, but also requires sensitivity to social-emotional aspects and child welfare (Sheridan et al., 2009). Teacher quality is a key determinant in creating a learning environment that is safe, stimulating, and supportive of children's exploration. Therefore, the pedagogical competence of ECE teachers must reflect a holistic and reflective approach (Darling-Hammond et al., 2020). Building on this foundational understanding, the following sections examine each component of the proposed 4.0 model, beginning with learning innovation as a catalyst for pedagogical renewal.

2.2. Learning Innovation as a Pillar of Pedagogical Renewal

Innovation in learning reflects teachers' ability to create new, creative, and adaptive approaches to improve the effectiveness of the learning process. In ECE, innovation is important for stimulating

children's curiosity and active participation (Craft, 2010). Innovative teachers can integrate technology meaningfully, use structured play methods, and create flexible and responsive learning environments (Falloon, 2020). Technology-based pedagogical innovation in early childhood education contributes to children's engagement and independence (Chai et al., 2013). This confirms that innovative competence is an integral part of modern pedagogy. While innovation provides the technological foundation, creativity serves as the pedagogical catalyst that transforms digital tools into meaningful learning experiences.

2.3. Teacher Creativity in Early Childhood Education

Creativity in early childhood education is not only related to artistic activities but also involves flexible thinking, problem solving, and the use of varied learning approaches (Craft et al., 2007). Creative teachers can design challenging and enjoyable activities and facilitate children's individual expression optimally. Creativity must be developed through open interaction, symbolic play, and active exploration (Torrance, 2003). In the context of pedagogical competence, teachers' ability to manage creativity is an important indicator in supporting the holistic development of children's potential. However, both innovation and creativity must be grounded in quality social interactions to achieve holistic child development.

2.4. Social Interaction as the Basis for Holistic Development

Social interaction in ECE has a significant impact on children's language development, emotions, and social skills (Whitebread et al., 2012). Teachers act as facilitators in building warm, responsive, and supportive relationships—which form the basis for children to learn to cooperate, understand emotions, and build empathy. The theory of the Zone of Proximal Development [ZPD] emphasizes that effective learning occurs in a social context, where the role of the teacher as a mediator is crucial (Vygotskij & Cole, 1981). Therefore, high-quality social interaction is an integral part of pedagogical competence. The integration of innovation, creativity, and social interaction requires systematic pedagogical implementation aligned with digital-age principles.

2.5. Implementation of Pedagogy 4.0: Integration of Technology and Humanization

Pedagogical Concept 4.0 refers to a technology-based learning approach but still places humanization at the center of the learning process (Kontkanen et al., 2023). This includes the integration of digital technology, project-based learning, collaboration, and data literacy within a framework that holistically builds children’s character. In the ECE context, Pedagogy 4.0 must be implemented carefully, ensuring that the use of technology supports children's exploration, imagination, and participation, rather than replacing them (Edwards, 2017). This shows that teachers need to be trained not only in technical skills but also in critical reflection on the meaning of pedagogy in the digital age.

Based on a synthesis of various recent studies (Kontkanen et al., 2023), the 4.0 pedagogical competency model for ECE teachers can be formulated into four core dimensions: (1) digital learning innovation, (2) pedagogical creativity, (3) social-emotional interaction, and (4) critical reflection. Digital learning innovations include mastery of educational technologies such as interactive applications, augmented reality, or simple robotics tailored to children's developmental stages (Papadakis et al., 2021). However, technology must be balanced with pedagogical creativity, namely, the ability to design project-based activities, sensorimotor exploration, and modification of educational toys using local materials. However, technology must be balanced with pedagogical creativity, namely the ability to design project-based activities, sensorimotor exploration, and modification of educational toys using local materials (Burnard & Dragovic, 2015). Meanwhile, social-emotional interaction is the foundation for ensuring that technology does not isolate children but rather strengthens collaboration and empathy through methods such as digital storytelling or role-playing (Hatzigianni, 2018). Finally, critical reflection is needed to evaluate the effectiveness of learning strategies and adjust them to the individual needs of children (Tang et al., 2023).

The interconnection between these competencies is symbiotic. Technological innovation has a positive impact only when combined with creative approaches and meaningful social interactions (Marsh et al., 2016). For example, using tablets for digital drawing will be more effective when followed by group discussions about the stories behind images. Conversely, creativity without technological support may not adequately prepare children for future digital literacy (OECD, 2020). Critical reflection acts as a "connector" that ensures the other three competencies are applied in a balanced and contextual manner (Falloon, 2020).

To measure this competency, recent research has recommended a multimodal approach. Performance observation (classroom assessment) can be conducted using a rubric that includes indicators such as variety in the use of digital media, quality of social–emotional scaffolding, and flexibility in responding to children's interests (Pianta et al., 2008). Portfolio analysis, including the documentation of innovative projects, learning plans, and teacher reflection notes (Darling-Hammond et al., 2020). A 360° survey involving feedback from peers, parents, and—for older children—a simple statement about the learning experience (Whitebread et al., 2012). Simulation-based assessment, for example, through virtual teaching scenarios to test teachers' responses to dynamic classroom situations (Wijaya et al., 2024).

3. Method

3.1. Research Design

This study used a cross-sectional design and employed a Confirmatory Factor Analysis technique to examine the proposed measurement model. CFA was chosen because it allows for testing the construct validity of a previously developed theoretical model (Hair et al., 2016). This study examined the latent structure of the Pedagogical Competence Model 4.0, which consists of four main constructs: Learning Innovation, Creativity, Social Interaction, and Pedagogical Implementation.

3.2. Participants and Procedure

Participants in this study consisted of ECE teachers who had at least one-year active teaching experience from various public and private ECE schools in Indonesia. The study was advertised through ECE teachers' networks on social media and direct communications to researchers' own networks. Those who were interested to participate could access the survey link which led them to the online survey platform where they found the study's informed consent form and survey questions. A total of 351 ECE teachers were recruited as participants. To allow comparison between teachers' competence (i.e., certified and uncertified), the study advertisements targeted teachers with certified and non-certified teaching competence.

This study also targeted participants from various demographic variables. The targeted participants represented large islands with characteristics of both developed and developing cities. Data collection was conducted online and offline over three months. Questionnaires were distributed via an online survey platform for online data collection. For offline respondents, the research team visited several ECE institutions. Each participant was provided with an explanation of the research objectives and signed an informed consent form. To obtain responses, questionnaires were sent out along with invitations to participate as respondents. Respondents began by agreeing to participate voluntarily before completing the surveys. They had the option to participate or decline to participate. To obtain objective data, the questionnaires were objective in nature, and students were informed that the information provided would be kept confidential and used only for research purposes.

3.3. Measures

The ECE teacher's competency 4.0 scale measured the competence of ECE teachers in the pedagogical competency model 4.0. This measure was developed based on the pedagogical competency framework 4.0, which consists of four main dimensions: learning innovation,

creativity, social interaction, and implementation of pedagogical competencies (Craft et al., 2007; Falloon, 2020; Kontkanen et al., 2023; Whitebread et al., 2012). The items were adapted to fit the learning context fin early childhood education. The measure was developed based on a scale development guideline and principles. The measure went through content validity testing by three early childhood education experts and internal consistency reliability testing (Cronbach's Alpha > .80) before the main data collection was conducted. The measures were administered using Likert-type scale with options ranged from strongly disagree (1) to strongly agree (4). One of the items is "I always try to apply the latest technology in classroom learning" for the dimension of learning innovation, and "I encourage children to express themselves through various artistic and creative activities" for the dimension of creativity.

This scale differs from existing pedagogical competency measures in several key aspects. First, it integrates four dimensions that are typically measured separately in traditional instruments. Second, it specifically addresses digital-era competencies rather than generic teaching skills. Third, it was contextually adapted for Indonesian ECE settings, incorporating cultural and educational system considerations. Fourth, it emphasizes the interconnected nature of competencies rather than treating them as independent constructs. Existing measures often focus on single dimensions or lack the digital integration emphasis essential for contemporary early childhood education.

Data collection was conducted entirely online over three months using a secure survey platform. The study was advertised through ECE teacher networks on social media and direct communication through professional networks to reach participants across major Indonesian islands representing both developed and developing areas. Interested teachers accessed the survey through a provided link that directed them to an online platform containing the informed consent form and survey questions. All participants provided digital informed consent before completing surveys. Participation was entirely voluntary, and respondents could withdraw at any time during the survey process. To ensure data quality and confidentiality, participants were assured that all information would be used solely for research purposes, kept anonymous, and stored securely on encrypted servers.

The second section contained questions that explored respondents' demographic information using self-report questions. The information collected included gender, university, study program, type of kindergarten/ECE where they taught, highest level of education, type of highest level of education, length of teaching experience, and level of information technology proficiency (i.e., very poor, poor, fair, and proficient). Certification status (i.e., certified or non-certified) and employment status (e.g., permanent) were also reported. Educational background was also grouped based on the educational level required to teach at ECE schools in Indonesia (e.g., bachelor's and master's degrees). Teaching experience was categorized into five groups (i.e., ≤ 5, 6 – 10, 11 – 15, 16 - 20, and > 20 years). The frequency of training participation in the last two years were grouped into four categories (i.e., never, 1-3 times, 4-6 times, and more than 6 times).

The third section contains statements representing the five main dimensions of 4.0 pedagogical competence for ECE teachers. Each dimension contained five items for learning innovation, social interaction, implementation of pedagogical competence, and creativity, which consisted of six items. The demographic data of the respondents are presented in Table 1.

Table 1 presents the demographic information of 351 participants involved in this study. The majority of respondents were female (98.58%), while only 1.42% were male, indicating that the early childhood education profession is predominantly occupied by women. In terms of educational institutions, 60.11% of participants were from public universities, and 39.89% from private universities. Most respondents majored in Early Childhood Education (66.38%), with 84.62% working in private early childhood centers, and 15.38% in public institutions.

The majority of respondents hold a bachelor's degree in Early Childhood Education [ECE] or Psychology (203 respondents; 57.83%), followed by 81 respondents (23.08%) with bachelor's degrees in other fields beyond ECE, Psychology, and Non-Education. In addition, 38 respondents

Table 1
Demographic information of participants (n= 351)

Category	*n*	*%*
Gender		
Female	346	98.58
Male	5	1.42
Type of Education Institution		
Public University	211	60.11
Private University	140	39.89
Education Program		
Early Childhood Education	233	66.38
Islamic Early Childhood Education	32	9.12
Christian Early Childhood Education	2	0.57
Others	84	23.93
Type of Early Education Center		
Public	54	15.38
Private	297	84.62
Field of Last Education		
High School (Science/Social/Language)	20	5.70
Diploma (Education/Non-Education)	9	2.56
Bachelor's in ECE/Psychology	203	57.83
Bachelor's in Non-Education /Education Other than ECE/Psychology	81	23.08
Postgraduate (Education/Non-Education	38	10.83
Educational Level		
High School	20	5.70
Diploma	8	2.28
Undergraduate	283	80.63
Postgraduate	40	11.40
Years of Teaching Experience		
< 5 years	87	24.79
6-10 years	57	16.24
11-15 years	63	18.80
16-20 years	66	17.95
> 20 years	78	22.22
Teacher Certification		
Yes	204	58.12
No	147	41.88
Employment Status		
Civil Servant	76	21.65
Non-Civil Servant	275	78.35
Training Participation (past 2 years)		
Never	22	6.27
Rarely (1–3 times)	172	49.00
Often (4–6 times)	121	34.47
Always (> 6 times)	36	10.26
ICT Proficiency Level		
Very poor	2	0.57
Poor	45	12.82
Fair	269	76.64
Proficient	35	9.97

(10.83%) completed postgraduate studies, 20 respondents (5.70%) graduated from high school, and 9 respondents (2.56%) hold diploma degrees. Overall, these results indicate that most respondents have higher education backgrounds relevant to early childhood education.

Regarding employment status, 21.65% were civil servants, while 78.35% were non-civil servants. For educational level, the majority held an undergraduate degree (80.63%), followed by postgraduate (11.40%), while only a small portion completed high school (5.70%) or diploma programs (2.28%). In terms of teaching experience, 24.79% had less than 5 years of experience, 16.24% had 6–10 years, 18.80% had 11–15 years, 17.95% had 16–20 years, and 22.22% had more than 20 years of teaching experience. A total of 58.12% of respondents were certified teachers, while 41.88% had not yet obtained certification.

Concerning training participation over the past two years, most teachers rarely attended training (49.00%), 34.47% attended training frequently (4–6 times), 6.27% never attended any training, and only 10.26% were very active (>6 times).

Finally, regarding ICT proficiency level, almost half of the respondents were in the poor category (12.82%), followed by fair (76.64%), proficient (9.97%), and very poor (0.57%). These findings indicate that the digital competence of early childhood teachers remains relatively low and requires further enhancement to meet 21st-century teaching demands.

3.5. Data Analysis Techniques

The data were analyzed using Confirmatory Factor Analysis techniques with Robust Maximum Likelihood [RML] estimators in JASP software. The model evaluation was conducted in two stages: (1) testing the measurement model to assess construct validity and indicator reliability, and (2) testing multigroup invariance (Byrne, 2016) to determine model consistency between certified and uncertified teachers. The cut-off values for each fit index will take into account the standards commonly used in research (Hair et al., 2016).

4. Results

4.1. Model Fit

The CFA of the four main constructs in the Pedagogical Competency Model 4.0 showed that the model fits the empirical data very well. The results of the model fit indices are shown in the Table 2.

Table 2
Summary of Model Fit Indices

Model Indices	*Value*	*Cut-off value*
Chi-Square/ df	2.56	CMIN/df < 4
Comparative Fit Index (CFI)	0.95	≥ 0.90
Tucker-Lewis Index (TLI)	0.94	≥ 0.90
Root Mean Square Error of Approximation (RMSEA)	0.07	≤ 0.08
Standardized Root Mean Square Residual (SRMR)	0.04	≤ 0.08
Goodness of Fit Index (GFI)	0.88	≥ 0.80

The result of Table 2 shows that the Chi-Square/df (CMIN/df) value is 2.56, which is below the recommended threshold of 4, indicating an acceptable level of model fit. The Comparative Fit Index [CFI] value of 0.95 and the Tucker-Lewis Index [TLI] value of 0.94 both exceed the minimum acceptable level of 0.90, suggesting a good correspondence between the hypothesized model and the observed data.

Furthermore, the Root Mean Square Error of Approximation [RMSEA] value of 0.07 and the Standardized Root Mean Square Residual [SRMR] value of 0.04 are both within the acceptable limits of ≤ 0.08, indicating a low level of approximation and residual errors. The Goodness of Fit Index [GFI] is 0.88, exceeding the cut-off value of 0.80, which demonstrates that the model adequately fits the data. Overall, these fit indices meet the recommended criteria, implying that the proposed model demonstrates a good level of fit and is appropriate for further analysis.

4.2. Construct Validity and Reliability

Construct validity was tested using the Average Variance Extracted [AVE] value, while reliability was measured using Cronbach's Alpha (*a*) coefficient and Composite Reliability (ω). The complete results are presented in Table 3.

Table 3
Construct of AVE and Reliability

Construct	*AVE*	*Cronbach's a*	*Composite Reliability (ω)*
Learning Innovation	0.57	.87	.86
Creativity	0.70	.93	.93
Social Interaction	0.71	.92	.93
Pedagogical Implementation	0.56	.87	.86

The AVE values for all constructs were above the minimum threshold of .50, indicating that the indicator variables could explain more than 50% of the variance in their latent constructs (Fornell & Larcker, 1981). Reliability values (α and ω) > .85 indicate a very good internal consistency of the instrument.

4.3. Factor Loading

Table 4 presents the detailed standardized factor loadings for each construct in the measurement model, namely Learning Innovation, Creativity, Social Interaction, and Pedagogical Implementation. The factor loading values indicate the strength of the relationship between each observed indicator and its respective latent construct. According to Hair et al. (2021), standardized loadings of 0.50 or higher are considered acceptable, reflecting that the indicators sufficiently represent their underlying constructs.

Table 4
Detailed Factor Loadings for Each Construct

						95% Confidence Interval	
Factor	*Indicator*	*Std. estimate*	*Std. Error*	*z-value*	*p*	*Lower*	*Upper*
Learning Innovation	IP_1	0.600	0.039	15.329	< .001	0.523	0.676
	IP_2	0.563	0.042	13.460	< .001	0.481	0.645
	IP_3	0.582	0.040	14.602	< .001	0.504	0.661
	IP_4	0.557	0.041	13.747	< .001	0.478	0.636
	IP_5	0.504	0.040	12.697	< .001	0.426	0.582
Creativity	Kr_1	0.624	0.040	15.459	< .001	0.545	0.703
	Kr_2	0.597	0.038	15.553	< .001	0.522	0.673
	Kr_3	0.619	0.043	14.299	< .001	0.534	0.704
	Kr_4	0.630	0.042	14.957	< .001	0.548	0.713
	Kr_5	0.635	0.039	16.404	< .001	0.559	0.710
	Kr_6	0.602	0.035	17.152	< .001	0.533	0.671
Social Interaction	IS_1	0.669	0.042	15.807	< .001	0.586	0.752
	IS_2	0.649	0.042	15.546	< .001	0.567	0.730
	IS_3	0.638	0.041	15.522	< .001	0.557	0.718
	IS_4	0.617	0.044	13.879	< .001	0.530	0.704
	IS_5	0.580	0.046	12.653	< .001	0.490	0.670
Pedagogical Implementation	PK_1	0.526	0.042	12.557	< .001	0.444	0.608
	PK_2	0.593	0.034	17.309	< .001	0.526	0.661
	PK_3	0.516	0.036	14.201	< .001	0.445	0.587
	PK_4	0.498	0.043	11.626	< .001	0.414	0.582
	PK_5	0.524	0.045	11.730	< .001	0.436	0.612

All indicators in the four constructs had standardized factor loadings above 0.50 and were statistically significant at $p < .001$, as shown in Table 4. This finding indicates that each indicator contributes significantly to measuring its respective construct. The z-values, which exceed the critical value of 1.96, further confirm that all loadings are significant. Additionally, the 95% confidence intervals for all indicators do not include zero, providing additional evidence for the strength and reliability of the relationships.

The summarized results in Table 5 show that the range of factor loadings varies between 0.498 and 0.669, with mean loading values ranging from 0.532 to 0.631 across the constructs. The constructs Creativity and Social Interaction demonstrate the highest average loadings (0.617 and 0.631, respectively), indicating stronger indicator representation compared to other constructs.

Table 5
Summary of Factor Loadings by Construct

Construct	*Number of Indicators*	*Range of Factor Loadings*	*Mean Factor Loading*	*Validity Remark*
Learning Innovation	5	0.504 – 0.600	0.561	Acceptable
Creativity	6	0.597 – 0.635	0.617	Good
Social Interaction	5	0.580 – 0.669	0.631	Good
Pedagogical Implementation	5	0.498 – 0.593	0.532	Acceptable

Based on Hair et al. (2021), standardized loadings above 0.50 are considered acceptable, while values approaching 0.70 are regarded as strong. Therefore, all constructs in this model achieve acceptable to good convergent validity, confirming that the indicators reliably represent the latent constructs of Learning Innovation, Creativity, Social Interaction, and Pedagogical Implementation within the framework of Pedagogical Competence 4.0.

4.4. Discriminant Validity

Discriminant validity between constructs was tested using the Heterotrait-Monotrait Ratio [HTMT]. All HTMT values were below the threshold of 0.90, indicating that each construct had a clear conceptual difference (see Table 6). These results reinforce previous findings that the constructs in the Pedagogical Competence 4.0 model are distinctive and do not empirically overlap in meaning.

Table 6
Discriminant Validity Assessment (HTMT)

Construct 1	*Construct 2*	*HTMT Value*
Learning Innovation	Creativity	.87
Learning Innovation	Social Interaction	.80
Learning Innovation	Pedagogical Implementation	.81
Creativity	Social Interaction	.93
Creativity	Pedagogical Implementation	.83
Social Interaction	Pedagogical Implementation	.81

The error variances are also within acceptable limits. In addition, there are double-headed arrows between the main constructs that indicate strong correlations between Learning Innovation [InP] and Creativity [Krt] ($r = .83$), Creativity [Krt] and Social Interactions [InS] ($r = .84$), and Social Interactions [InS] and Pedagogical Implementation [PKP] ($r = .82$). This indicates that the four dimensions are significantly interconnected in shaping pedagogical competence 4.0.

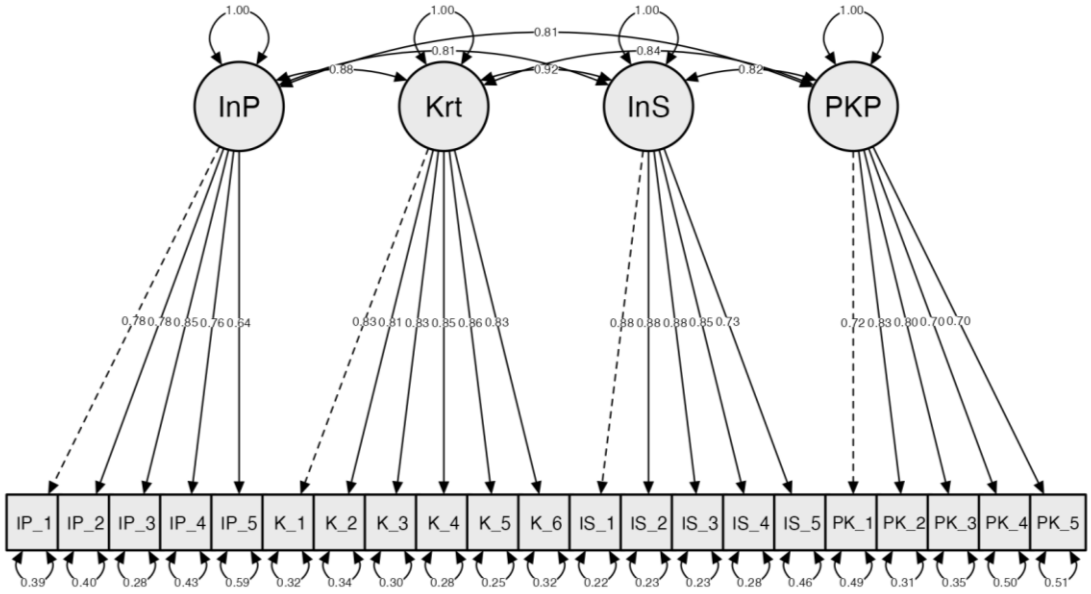
4.5. Measurement Model

The CFA measurement model visualization, which comprises four primary constructs, is shown in Figure 1. This path diagram illustrates the relationships between the latent constructs (items InP, Krt, InS, and PKP) and their indicators, as well as the correlations between the constructs.

Figure 1 shows that all items have significant standardized loading values ($p < .001$), ranging from .50 to .78. This indicates that these items are valid representations of the constructs they are measuring. For example, indicators of IP_1 through IP_5 loaded on the Learning Innovation (InP) construct, with the highest loading of 0.78. Meanwhile, the creativity items (K_1 through K_6) showed the largest contribution, with loadings approaching 0.63.

This visualization (see Figure 1) reinforces the previous numerical findings that the model structure is statistically and empirically valid and reliable.

Figure 1
Plot Model



The Pedagogical Competency Model 4.0 demonstrates a valid, reliable, and statistically appropriate measurement model structure. The four constructs (innovation, creativity, social interaction, and pedagogical implementation) are strongly interconnected and support a holistic approach to ECE.

5. Discussion

The results of this study indicate that the Pedagogical Competency Model 4.0, which consists of four constructs—learning innovation, creativity, social interaction, and pedagogical implementation—has strong construct validity and reliability, as well as a statistically stable factor structure. These findings provide empirical support for Vygotsky's sociocultural theory and contemporary digital pedagogy frameworks. The strong interconnections between constructs align with Vygotsky's emphasis on the social nature of learning, where innovation, creativity, and interaction work synergistically rather than in isolation (Vygotskij & Cole, 1981). This holistic approach reflects Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge framework, which emphasizes the integration of technology, pedagogy, and content. The high factor loadings for creativity support Craft et al.'s (2007) assertion that teacher creativity serves as a catalyst for meaningful learning experiences in early childhood education.

5.1. Theoretical Implications

The model visualization in the CFA path diagram also displayed close interconnections among the constructs. The high correlations between learning innovation, creativity, social interaction, and pedagogical implementation indicate that the pedagogical competence of ECE teachers is integrative. Teachers who exhibit innovative capabilities also tend to demonstrate high levels of creativity, foster strong social interactions with their students, and effectively implement pedagogical principles in their classrooms.

This model also illustrates that creativity plays the most dominant role—both statistically and practically—supporting the construct's central position in contemporary pedagogical approaches. The reciprocal relationships among constructs suggest that improvement in one dimension positively influences the others, which is essential for the ongoing professional development of teachers.

This is consistent with Vygotsky and Cole's theory on the importance of social interaction in learning, wherein meaning construction occurs through directed and supportive interpersonal relationships (Vygotskij & Cole, 1981). Previous literature also emphasizes that creativity is not merely an individual expression but is closely linked to teachers' flexibility in designing contextual and challenging learning experiences (Craft et al., 2007). Furthermore, Beneventi emphasizes that humanistic digital pedagogy is key to integrating technology meaningfully, without losing the essence of human relationships in the learning process (Beneventi, 2024).

Thus, this model is not only empirically robust but also underpinned by a solid theoretical foundation drawn from various recent educational studies. Theoretically, high-level model validity confirms that the four developed constructs are integral components of modern pedagogical competence. Learning innovation—evidenced by indicators such as the use of new approaches, digital media, and experimental strategies—plays a crucial role in creating a dynamic, child-responsive learning environment (Falloon, 2020). Innovation is not only about technology but also concerns how teachers craft learning experiences that are enjoyable and meaningful (Chai et al., 2013).

The creativity construct showed the highest loading among all dimensions, which aligns with the finding that teacher creativity is a key catalyst in early childhood learning (Craft et al., 2007). Teachers who can stimulate imagination, provide space for exploration, and adapt their approaches to children's interests will create a meaningful learning environment that supports children's cognitive and emotional development.

The dominance of creativity in our model reflects what Burnard and Dragovic (2015) term 'collaborative creativity,' where teachers facilitate rather than direct creative processes. This finding supports recent research by Tang et al. (2023) showing that effective digital-age teachers employ 'high-tech, high-touch' strategies, combining technological innovation with deep human connection. The strong correlation between creativity and social interaction validates Hatzigianni's (2018) assertion that technology integration must preserve and enhance rather than diminish social-emotional learning opportunities.

The construct of social interaction has also been proven to be significant. This reinforces the theory of Vygotskij and Cole that early childhood learning occurs optimally through directed social interactions (Vygotskij & Cole, 1981).

The social interaction construct was also highly significant. This reinforces the theory that optimal early childhood learning occurs via structured social interactions. Teachers play the role as scaffolder, facilitating secure interpersonal relationships, supporting collaboration, and providing constructive feedback. The quality of teacher-student interactions is a key indicator of the effectiveness of ECE (Whitebread et al., 2012).

The implementation of pedagogy as the final dimension indicates the teacher's ability to integrate the three previous aspects into concrete actions in the classroom. This reflects reflective abilities, needs-based planning, and the execution of learning in accordance with a holistic developmental framework (Beneventi, 2024; Pantić & Wubbels, 2010). Although the loading value for this dimension is relatively lower than the others, this does not diminish the importance of this dimension as the "backbone" of overall pedagogical competence 4.0.

The results of this study are in line with the findings of Falloon, who stated that 21st-century teacher competencies involve digital literacy, pedagogical flexibility, and social-emotional skills (Falloon, 2020). This consistency reinforces the position of the model developed in the context of the international literature. Furthermore, the alignment of this model with the values of Developmentally Appropriate Practice [DAP] reinforces that pedagogical approaches based on

innovation and interaction are not in conflict with child development principles; rather, they serve as practical manifestations of these principles (Copple et al., 2009).

Furthermore, demonstrated that kindergarten teachers' competencies vary across dimensions and that contextual factors shape their professional development needs (Gallego & Caingcoy, 2021).

5.2. Practical Implications

From a practical perspective, these findings provide strategic direction for ECE teacher professional development. The validated model can serve as a self-assessment tool enabling teachers to evaluate and reflect on areas requiring enhancement. For teacher training institutions, this framework offers a comprehensive curriculum structure emphasizing technology integration, creativity development, and social-emotional learning rather than traditional fragmented approaches. Policy development institutions can use this model to establish adaptive and sustainable pedagogical competency standards that move beyond generic requirements to address digital-age specific needs.

For example, teacher training should no longer solely focus on planning Daily Lesson Plans but must incorporate modules on digital exploration, the development of child-interest-based activities, and nurturing sensitive emotional interactions.

This finding also opens up opportunities to redefine the role of ECE teachers as visionary learning facilitators, rather than merely as conveyors of knowledge. With this model, teachers are expected to become agents of change, capable of creating a reflective, collaborative, and innovative learning environment.

5.3. Limitation and Future Research Directions

Although the results are robust, this study has certain limitations. First, the data were cross-sectional, making it impossible to capture the dynamics of competency changes over time. Second, all data were obtained through self-reports, which may have introduced perception biases. Future research should consider triangulating the findings with classroom observations and in-depth interviews.

For ECE practitioners, including teachers and principals, this model can be used as a tool for self-reflection and periodic assessment of pedagogical competence. Continuous training should be integrated, covering areas such as educational technology, creativity development, and the strengthening of social relationships in the classroom. Furthermore, an interactive, collaborative, and participatory learning environment should be developed in accordance with the principles of pedagogy 4.0.

For teacher training institutions and the government, the design of an ECE teacher training curriculum should be based on the four constructs of this model. The results of this study can serve as a basis for developing national standards for ECE pedagogical competencies that are more adaptive to the changing times. It is also important to promote teacher certification and professional supervision programs that assess innovative and holistic aspects, not merely administrative requirements.

For future researchers, longitudinal research is recommended to observe changes in teacher competence over time. The use of data triangulation methods, such as classroom observation and case studies, will strengthen the validity of the findings. Finally, the generalizability of this model should be tested in other contexts, including primary and non-formal education.

6. Conclusion

This study successfully developed and validated Pedagogical Competence Model 4.0, which consists of four core constructs: learning innovation, creativity, social interaction, and pedagogical implementation. The model demonstrated strong construct validity, high reliability, and excellent model fit based on the CFA analysis. Each construct complements the others and forms an essential foundation for a holistic approach to ECE in the digital era. This model makes a

significant contribution to both literature and practice in early childhood education by offering a conceptual framework aligned with the demands of the 21st century. Learning innovation plays a pivotal role in creating dynamic and adaptive learning environments. Teacher creativity emerges as a dominant factor in fostering meaningful exploration and learning. High-quality social interaction strengthens children's social–emotional development and facilitates learning through positive interpersonal relationships.

Despite these robust findings, several limitations should be acknowledged. First, the cross-sectional design prevents capturing competency development dynamics over time. Second, reliance on self-report data may introduce perception biases. Future research should employ longitudinal designs and triangulate findings through classroom observations, student outcomes assessment, and peer evaluations to strengthen validity. Moreover, effective pedagogical implementation reflects teachers' ability to translate all competencies into real practice in the classroom.

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Appendix 1. Research Questionnaire

"EARLY CHILDHOOD TEACHERS' PERCEPTIONS OF PEDAGOGICAL COMPETENCE 4.0 (LEARNING INNOVATION, CREATIVITY, AND SOCIAL INTERACTION) IN SUPPORTING EARLY CHILDHOOD DEVELOPMENT"

Part 1: Learning Innovation

No	Statement	Rating			
		1	2	3	4
1	I always try to apply the latest technology in classroom learning.				
2	I use various digital media to support early childhood learning				
3	I adapt the curriculum using innovative approaches relevant to early childhood development.				
4	I implement project-based or creative learning activities to enhance children's understanding.				
5	I use online learning platforms to support children's home learning.				

Part 2: Creativity

No	Statement	Rating			
		1	2	3	4
1	I encourage children to express themselves through various artistic and creative activities.				
2	I encourage children to develop critical thinking skills.				
3	I frequently look for new ways to make learning more engaging for children.				
4	I give children freedom to imagine and try new things in learning.				
5	I use various creative methods to teach basic concepts to children.				
6	I involve exploration and experimentation as important elements in early childhood learning.				

Part 3: Social Interaction

No	Statement	Rating			
		1	2	3	4
1	I teach values of cooperation through group activities.				
2	I teach empathy through real-life practice or social situations..				
3	I provide opportunities for children to interact in various classroom social settings				
4	I support children in resolving conflicts through good communication.				
5	I involve parents in learning activities to support children's social development.				

Part 4: Pedagogical Competence 4.0 Implementation

No	Statement	Rating			
		1	2	3	4
1	I integrate age-appropriate digital content (interactive videos, educational games) into enjoyable learning activities.				
2	I create learning spaces that can adapt to children's needs, including dynamic thematic play corners.				
3	I can adjust my teaching approach based on children's spontaneous interests, not only fixed daily plans.				
4	I use AI-based tools or interactive content to stimulate children's thinking and imagination.				
5	I apply differentiated learning strategies and special tools to support the active participation of children with special needs.				