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Development of a Four-Factor Structure Framework for Artificial Intelligence Literacy (AIL) of Pre-service Teachers in the Philippines

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Abstract

As Artificial Intelligence (AI) continues to reshape the educational landscape, pre-service teachers need strong AI competencies to navigate the AI-driven job market. This study aimed to develop and validate a 24-item instrument based on a four-factor structure of the AI Teaching and Learning Framework: Understanding, Use and Application, Evaluation, and Ethics. Guided by a three-stage scale development model, the instrument underwent expert reviews, pilot testing, and exploratory factor analysis using a cross-sectional survey of 310 pre-service teachers at a state university. Results confirmed the four-dimensional structure, which demonstrated excellent reliability, high sampling adequacy, and significant construct validity. This study offers a validated tool specifically tailored for pre-service teachers in the Philippine context, with a distinctive integration of an ethics dimension alongside understanding, application, and evaluation. It also embeds the ethics dimension for pre-service teachers to exercise ethical judgment and responsible AI use. This validated scale provides a practical and reliable instrument for curriculum design, teacher training programs, and policy development in the AI chatbot era. To strengthen generalizability and theoretical rigor, future research should pursue cross-institutional and cross-cultural validation with confirmatory factor analysis.

Keywords: artificial intelligence literacy, pre-service teachers, psychometric validation, scale development, exploratory factor analysis

1. Introduction

1.1 The Problem

Artificial Intelligence (AI) has increasingly evolved from an emerging innovation to a transformative force that redefines the understanding and delivery mechanisms for the education community. Generative AI tools like ChatGPT, intelligent tutoring systems, adaptive learning, and automated assessments are fundamentally challenging the types of learning that are possible and making critical instructional decisions. As AI becomes increasingly integrated into educational systems, teacher preparation programs must consider how to provide the technical competencies needed for students to deal with AI education while also inculcating the important critical and ethical understanding necessary for the responsible and effective use of these dynamic technologies (Long & Magerko 2020; Carolus et al. 2022).

It is essential to empower educators with a comprehensive understanding of the societal issues, redesign deliverable outcomes, and systemic reorientations related to AI-rich environments. Although academic interest in AI use is a continuous debate in the scientific community, the examination of AI literacy in teacher education is less mature. Existing instruments generally lack rigorous psychometric validation or are developed for non-educator populations (Karaca et al., 2021; Wang et al., 2023; Pinski & Benlian, 2023). Moreover, inconsistent frameworks and indicators hinder reliable measurement and comparisons of AI literacy across educational contexts. These limitations make it challenging for teacher educators, policy makers, and curriculum designers to align AI literacy with 21st-century teaching competencies. A significant challenge lies in the variability of definitions and operationalizations that complicates the establishment of reliable and valid assessment metrics (Beck, 2020; Dai et al., 2020).

1.2 Significance of the Study

Meanwhile, this study establishes a new, contextually informed measure of AI literacy in pre-service teachers. This is vital given teachers' pivotal role in shaping future learners' AI competencies that would need to adapt to an AI-driven global market. Anchored in a four-dimensional framework of AI literacy (Understanding, Use and Application, Evaluation, Ethics), the study offers conceptual clarity and empirical evidence to guide AI literacy integration in teacher education programs. The 24-item instrument is a diagnostic tool to assess readiness and assist in monitoring of AI readiness, making it appropriate for both development assessments and learning analytics.

Given the increasing adoption of AI in education, an instrument such as this serves as a potent catalyst for teacher preparation programs to develop essential resources that empower pre-service teachers to be knowledgeable and critically engaged in implementing ethically centered teaching practices. Literature underscores the value of AI literacy in boosting teacher confidence, engagement, and instructional effectiveness (Du et al., 2024). Ethical considerations in AI literacy would help pre-service teachers address questions of bias, equity, and societal impacts. This has important implications for research and practice, as it addresses an urgent methodological and pedagogical gap in approaching AI-driven education (Wijaya et al., 2024; Yu, 2025).

1.3 Statement of the Problem

The study aimed to develop a multidimensional instrument for measuring AI Literacy (AIL) among pre-service teachers within the context of contemporary teacher education. Anchored from the AI Teaching and Learning Framework, this study aimed for a theoretical contribution with empirical rigor to assess AI readiness for pedagogical integration. Specifically, it answers the following:

1. What are the core dimensions that constitute Artificial Intelligence Literacy (AIL) for pre-service teachers?
2. What psychometrically sound instrument can be developed to measure AI Literacy for pre-service teachers?
3. What factor structure does the developed instrument reveal through Exploratory Factor Analysis (EFA)?

2. Review of Related Literature

Artificial Intelligence (AI) in education, particularly the rise of chatbots, is a paradigm shift that is redefining the very essence of digital literacy and intellectual integrity in the 21st century. Not only does pedagogic expertise no longer center exclusively on traditional digital tools, but more recent instructional tasks now include developing an understanding of AI systems, critically consuming algorithmic insights, and ethically considering their usage in different classroom-based activities. Ng et al. (2021) conceptualized AI literacy as encompassing the knowledge, skills, attitudes, and values that enable individuals to successfully and responsibly engage with AI technologies. Drawing connections across cognitive, ethical, and practical dimensions of this multidimensional construct challenges the idea that AI literacy is just a matter of knowing techniques — it also includes evaluative thinking and ethical considerations.

In an evolving educational landscape shaped by Artificial Intelligence, Zhou & Schofield's (2024) proposed framework on AI Literacy stands out as a cognitive and behavioral forward-looking framework for preparing educators to navigate AI-integrated teaching and learning. The model includes four interconnected constructs: 1) Know and understand AI; 2) Use and apply AI; 3) Evaluate and Create with AI, and 4) AI Ethics. This framework offers a structured approach to AI literacy for teachers to progress from roots in basic conceptual understanding to more advanced cognitive engagement and ethical reasoning. The first proposed construct, Know and Understand AI elucidates essential knowledge about the fundamental ideas, mechanisms and restrictions of AI. The second, Use and Apply AI, focuses on how to incorporate AI tools into instructional design for creating innovative and flexible content. Furthermore, Evaluate and Create with AI helps to develop the ability to evaluate whether an AI output is valid, as well as adapt that output to local needs and create new examples of its use. Lastly, AI Ethics rounds out the rules for applying AI based on fairness, transparency, privacy and accountability. Woven from Bloom's Revised Taxonomy, these levels of cognitive skills run from those underlying basic memorization to multifaceted synthesis and ethical judgement, yielding credible theory along with real practice for curriculum planning, teacher training, and credentialing.

Empirical evidence strongly reinforces the value of AI use in advancing teaching effectiveness. Casal-Otero et al. (2023) stated that educators with higher AI literacy demonstrate a greater capacity to integrate AI tools purposefully for a more personalized instruction and promotion of innovative pedagogical practices. There is an urgency to embed comprehensive AI literacy training in teacher preparation programs (Casal-Otero et al., 2023) to develop future educators who can lead innovation while maintaining pedagogical integrity.

Although awareness of AI literacy's importance is growing, there is still a considerable void in the availability of rigorously validated instruments designed for the unique needs of teacher education. Existing tools are useful to some extent, but they do not align with the pedagogical approach, and one-dimensional tools cannot meet the multi-faceted

expectations of teaching in AI-enriched environments (Zhang et al., 2025; Karaca et al., 2021). The instruments that exist recently are often isolated in and around technical proficiency, missing key areas such as ethical reasoning, critical evaluation, and implementation of AI tools into learning designs. The gap is a major concern because fashioning programs for teacher education means being specific to individual context-sensitive pathways to strengths, weaknesses and actual intervention designs for AI readiness. Failing to have such tools in place risks AI training that is skin-deep and produces educators who are tech-savvy but pedagogically under-prepared in the intricacies of integrated AI. In addition, the lack of standardized, research-validated measures from a specific context also presents a barrier to the assessment of certain areas of functioning. Comparative research restricts the development of policy and hampers the application of relative best practices in multiple educational systems.

To move beyond a fragmented approach to AI literacy assessment, Fraser's (1998) three-stage development model is designed to produce a rigorously validated instrument tailored to the needs of teacher education. This model guides the process so the final instrument is empirically informed and pedagogically germane for teaching in AI-rich environments. These are vital for measuring the current state of AI literacy, planning curricular changes as needed, offering professional development opportunities, and being able to create evidence-based policies. Similarly, Du et al. (2024) reinforce the idea that quality, situation-sensitive tools and resources are fundamental for teachers to align AI in concert with the pedagogical goals of particular courses and maximize student learning impact. Most significantly, AI literacy initiatives will otherwise be implemented with no such validated instruments and therefore be inconsistent, haphazard or even pathetically removed from the classroom.

In a paradigm where the credibility of educational measurement must balance psychometric rigor with pedagogical relevance, anchoring AI literacy assessment in Fraser's model would allow for a stronger and more theoretically cohesive framework. Preparing and iterating expert review and field-testing sequences at a larger scale focuses on gathering evidence that conforms not only to psychometric standards but also to the pedagogic complexities of teacher education. Furthermore, the framework flexibly harnesses cultural, institutional and curricular diversity, facilitating adaptation in diverse educational settings around the world without sacrificing validity.

With AI becoming a key hallmark of modern education, the establishment of reliable and valid multidimensional instruments applicable to pre-service teachers holds both theoretical and practical relevance. In the abstract, these kinds of tools operationalize nuanced and sophisticated models of AI literacy in a manner that can be measured, so that meaningful decisions around instructional planning, curriculum alignment, and targeted intervention are possible. No doubt, they offer practical inputs to teacher education programs that seek to comprehensively evaluate, track and improve AI preparedness. More importantly, the proposed framework of Zhou and Schofield (2024) allows institutions to go beyond isolated technical training to integrate AI more systematically with their curriculum in the context of a richer pedagogical and ethical perspective. This integration sets an incredibly high bar for educators, who must not only be expert users of AI technologies but also smart and prudent custodians of their classroom applications. Truly, the practical implications are substantial.

Results from the validated instruments can become a catalyst to reform teacher preparation programs, courses, workshops and experiences that are student-centered rather than AI-centered. They can support policy formation at the institutional and government level and translate AI integration efforts into a data-driven substrate, validated against pedagogical coherence. Nevertheless, longitudinal assessment of AI literacy development can allow educators and policymakers to evaluate the impact of interventions over time. Educators with deep knowledge of AI and how it can be used to improve learning outcomes, will deconstruct its implications for equity, inclusivity, and ethical practice. AI is thus not just another tool of technology for use in education but rather a supplementary component that may help to accelerate the high-quality, human-centered nature of learning in an age of unprecedented advancement. Integration of AI into the educational system brings a lot of opportunities, but at the same time, raises various ethical issues to be handled.

As artificial intelligence becomes increasingly embedded in educational practice, the discourse is shifting beyond technical proficiency toward an equally urgent concern: the ethical imperative that guides its responsible use (Vallis et al., 2024; De Gagne et al., 2024). AI adoption in education unveiled that educators should be educated not only to teach AI literacy but also to engage with the ethical dimension of new AI scientific artefacts. Some research elucidates the importance of making students realize the dual role they play as users and creators of AI, especially when it comes to building a culture of ethics (Akgün & Greenhow, 2021; Sanusi et al., 2024).

To prepare pre-service teachers for an AI-driven future demands more than technical know-how, it requires cultivating a critical and ethical lens that ensures technology serves both learning and society. Consequently, through ethical training, future educators can learn to look past technical limitations and see how it may impact society while creating learning settings. There is a critical necessity for a validated and multi-dimensional pre-service teacher´ AI literacy evaluation

tool. The primer underscores the necessity of ensuring educators are equipped with strong technical, critical and ethical capabilities that will enable them to effectively incorporate AI tools in their teaching efforts. Advancing AI literacy through validated assessment frameworks is not merely a scholarly pursuit but a decisive step toward shaping educators who can responsibly navigate, transform, and humanize education in the age of unprecedented advancement.

3. Method

3.1 Research Design

This study utilized a quantitative, cross-sectional instrument-development design aimed to determine the psychometric properties of an Artificial Intelligence Literacy (AIL) scale for pre-service teachers in the context of a state university in the Philippines. The research followed established scale development procedures that include content validation, pilot testing, and exploratory factor analysis (EFA) to examine construct validity and reliability (DeVellis & Thorpe, 2021). Data were collected at a single point in time from pre-service teachers, making a cross-sectional approach appropriate for the assessment of the initial factor structure and internal consistency of the instrument.

3.2 Study Setting and Population

The study was conducted at the College of Education of a state university, a higher education institution offering teacher education programs in Elementary Education. A total of 310 pre-service teachers voluntarily participated in the study. Convenience sampling was employed based on the accessibility and availability of the students during data collection. Participants met the inclusion criteria of being currently enrolled in the teacher education program and having completed at least one professional education course. The students who participated were from the second, third, and fourth years. Data were gathered through a self-administered survey, with voluntary participation ensured and anonymity maintained.

3.3 Data Gathering Procedure

This scale was developed using Fraser's (1998) three-stage model for instrument construction. A deductive approach was applied, comprising the following stages:

Stage 1 – Literature Review. A comprehensive review of literature was conducted on AI literacy levels, encompassing academic books, peer-reviewed research articles, conference proceedings, and other relevant materials. The review examined key components of AI integration in education, with particular emphasis on its application in service-learning contexts. Focus areas included issues and challenges in implementation, such as planning and collaboration, evaluation and needs assessment, training and orientation, and student placement. These thematic areas served as the conceptual foundation for developing the instrument's initial pool of items.

Stage 2 –Item Generation. Based on the literature review, 26 initial items were generated, each aligned with the identified themes. The most relevant and representative statements were grouped according to thematic categories. Repetitive and redundant items were removed, and double-barreled statements were restructured. An expert panel reviewed the initial draft, providing feedback on clarity, relevance, and comprehensiveness. After revisions, the scale was refined to 24 items across four subscales: Understand, Use and Apply AI, Evaluate and Create with AI, and AI Ethics.

Stage 3 – Pilot Testing. The refined 24-item instrument underwent pilot testing to assess reliability and internal consistency. Responses were collected from the target population, and Cronbach's alpha was computed to determine scale reliability. The resulting alpha coefficient was 0.96, indicating excellent internal consistency and confirming the suitability of the instrument for further validation.

3.4 Ethical Considerations

Ethical clearance for the study was secured from the Departmental Research Ethics Committee of the College of Education. Before data collection, participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any point without consequence. Informed consent was obtained before completing the questionnaire.

Confidentiality and anonymity were strictly upheld by ensuring that no identifying information was collected or linked to survey responses. All data were stored securely and used solely for research purposes. The study posed minimal risk to participants, as it involved only self-reported perceptions of AI literacy. Measures were taken to ensure that participation did not influence academic standing or course-related outcomes.

Moreover, the authors disclose the use of the ChatGPT free version for suggestions during brainstorming sessions and grammar checking purposes. Grammarly free version was also used for grammar checking purposes aside from ChatGPT. Likewise, Jamovi software was used for the Exploratory Factor Analysis.

3.5 Data Analysis

Data were analyzed using quantitative statistical procedures to evaluate the psychometric properties of the newly developed instrument. Descriptive statistics were computed to assess item performance and ensure that response distributions were acceptable for factor analysis.

Exploratory Factor Analysis (EFA) is a statistical technique used to identify the underlying structure of a set of variables was conducted to examine the construct validity of the instrument. Because EFA requires adequate correlations among items, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity were examined to verify whether the dataset met the assumptions for factor extraction.

Construct validity was assessed through EFA using minimum residual extraction and varimax rotation. Factor retention decisions were guided by eigenvalues greater than 1.0, scree plot interpretation, and theoretical alignment with the four-dimensional conceptual framework of AI literacy (Understanding, Use and Application, Evaluation, and Ethics). Items demonstrating low communalities, weak corrected item–total correlations, or significant cross-loadings were marked for potential revision or removal to improve structural clarity.

Internal consistency reliability was examined using Cronbach's alpha for both the overall instrument and each subscale, ensuring that the refined scale met established psychometric standards. The results from these analyses informed the validation and final structure of the instrument.

3.6 Reliability Analysis

The AI literacy 24-item instrument exhibits outstanding internal consistency with its reliability to measure pre-service teachers' competencies in artificial intelligence. With a Cronbach's alpha of 0.958, the AI Literacy instrument surpasses the commonly accepted benchmark of 0.90 for high reliability (George and Mallery, 2003), indicating strong interrelatedness among items and consistent measurement of the AI literacy construct. Complimenting this, McDonald's omega coefficient (ω=0.959) provides an even more robust estimate of reliability, particularly valuable when tau-equivalence assumptions are potentially violated, thus reinforcing the scales' psychometric strength. The reported mean score (M=4.22) reflects generally favorable AI literacy levels among respondents, signaling readiness to engage with AI concepts and applications. Meanwhile, the low standard deviation (SD = 0.532) suggests minimal response variability, underscoring a relatively uniform competence across the sample. These results attest to the instrument's reliability and its suitability for both research and practical assessment within the teacher education context.

4. Results

Table 1 presents the four subscales of the Artificial Intelligence Literacy (AIL) instrument which represent different competency domains. The 10-item Understand subscale measures basic AI literacy and focuses on understanding concepts and the operational principles necessary to improve learning. The 6-item Use and Apply AI subscale measures the capacity to apply acquired knowledge about AI to practical tasks. The 5-item Evaluation subscale captures higher-order thinking skills required for the critical examination, synthesis, and contextual understanding of AI outputs. The final sub-scale in AI Ethics (5 items) assesses moral reasoning, bias recognition, privacy awareness and the idea of responsible integration into educational practice. These dimensions define a psychometrically sound model for measuring multidimensional AIL, enabling the reliable assessment of cognitive, practical and ethical competencies. It serves as a diagnostic model on which to ground curriculum innovation and focused teacher preparation, leading ultimately to more easily monitored policy in this age of AI-integrated education.

Table 1. Original Version of Subscales, Item Distribution of the AIL Instrument for Pre-Service Teachers

Subscale	**Understand** (Know and understand the basic functions of AI tools to support learning.)
UND1	I have a clear understanding of the definition of AI, its scope, concepts, techniques, and foundational knowledge of AI algorithms.
UND2	I understand how to formulate effective prompts for Generative AI (GenAI) tools to explore and deepen my understanding of complex concepts.
UND3	I comprehend the function of AI-based note-taking tools in accurately capturing, organizing, and reflecting on key information.
UND4	I recognize how Generative AI can support ideation by generating diverse perspectives and initial concepts for creative and academic projects.
UND5	I understand how to use AI tools for mind mapping and thematic organization to enhance clarity and structure in my thinking.
UND6	I am aware of AI-assisted writing tools to refine my grammar and writing conventions, understanding how these tools support linguistic accuracy and coherence.
UND7	I am familiar of AI tools to interact with reading materials—summarizing, synthesizing, and analyzing content—to support comprehension and critical analysis.
UND8	I understand the collaborative functions of AI tools in facilitating peer interaction, idea sharing, planning, and dynamic concept visualization.
UND9	I hold an understanding of AI functionality to design professional-quality presentations and craft relevant bios for various purposes.
UND10	I know about the capabilities of Generative AI in image creation, recognizing how visual outputs can be tailored to support specific learning tasks.
Subscale	**Use and Apply AI** (Apply AI knowledge, concepts and applications to support learning.)
UAP1	I use Generative AI tools to review and synthesize information about teaching-learning.
UAP2	I utilize Generative AI tools to explore and gather information on a wide range of teaching methodologies, both traditional and contemporary, to enhance my instructional strategies and adapt to diverse learning needs.
UAP3	I engage in exercises where I use AI tools to tackle specific problems, which helps me develop analytical thinking and apply technology to create practical solutions in my work as a future educator.
UAP4	I engage in exercises where I use AI tools to analyze data and identify trends.
UAP5	I use AI tools for data analysis tasks, learning how to handle, process, and draw conclusions from large datasets.
*UAP6	I use AI tools to create multimedia content, such as videos or digital sketches.
Subscale	**Evaluation** (Evaluate AI-generated content enabling higher-order thinking skills development.)
EVAL1	I critically assess the accuracy and credibility of AI-generated content against reliable sources.
EVAL2	I analyze the logical coherence and relevance of AI outputs in relation to the task or problem at hand.
EVAL3	I evaluate AI-generated arguments or ideas, identifying biases, assumptions, and limitations.
EVAL4	I synthesize insights from AI content with my own knowledge to develop deeper interpretations or alternative perspectives.
EVAl5	I reflect on the contextual implications of using AI-generated content in academic or real-world scenarios.
Subscale	**AI Ethics** **(**Comprehend the moral and ethical consequences of AI and making informed decisions regarding its use in various contexts)
ETH1	I understand the clear policies regarding AI use in assessments, learning when and how AI can assist with idea generation and writing.
ETH2	I recognize potential ethical issues such as bias, privacy, and misinformation in AI-generated content.
*ETH3	I consider fairness, accountability, and transparency when deciding how to use AI tools. (removed)
ETH4	I reflect on the responsible use of AI, ensuring it aligns with ethical standards and community values.
ETH5	I make informed choices about using AI based on its potential risks and benefits in specific contexts.

*The items are discarded in the final version of the scale.

Table 2. Sampling Adequacy and Sphericity Tests for EFA

Constructs	**Kaiser-Meyer-Okin Measure of Sampling Adequacy**	**Bartlett's Test if Sphericity**
Understand	0.940	<.001
UAP	0.893	<.001
Ethics	0.895	<.001
Evaluation	0.895	<.001
All Constructs	0.952	<.001

The preliminary diagnostic results present compelling statistical evidence that the dataset is exceptionally well-suited for rigorous exploratory factor analysis (Table 2), as all subscales have Kaiser-Meyer-Olkin (KMO) values over the recommended minimum threshold of 0.50, indicating excellent sampling adequacy: Understand (0.940), Use and Apply AI (0.893), Ethics (0.895), and Evaluation (0.895). The inter-item correlations were low enough to make factor

identification feasible, which is consistent with Bartlett's Test of Sphericity, showing significant results ($\chi^2 = 6099$, df = 325, $p < .001$) for all constructs, indicating that the correlation matrices were not identity matrices and had enough common variance for factor analysis. A global KMO value of 0.952 confirms the appropriateness of the dataset for exploratory analysis, considered "excellent" in psychometric terms. This indicates that the dataset is statistically adequate to reveal the underlying factor structure, thus providing a strong empirical foundation for making inferences about the dimensional composition of the AI literacy instrument.

4.1 Exploratory Factor Analysis

The overall KMO value of 0.952 demonstrates excellent sampling adequacy, indicating that the dataset is highly appropriate for factor extraction. Bartlett's Test of Sphericity yielded a significant result ($p < 0.001$), confirming that the variables are sufficiently correlated and that the correlation matrix is not an identity matrix. These preliminary checks validate the suitability of the data for Exploratory Factor Analysis (EFA) and support the investigation of the underlying structure of the AI Literacy instrument.

Table 3. Initial Eigenvalues

Initial Eigenvalues	
Factor	**Eigenvalue**
1	12.0407
2	1.8322
3	1.2827
4	0.5047

The eigenvalue analysis (Figure 3) shows a decisive statistical insight into the underlying four-factor structure, revealing both the strength and nuance of the AI literacy construct. Following Kaiser's criterion (eigenvalues > 1.0), three factor emerged as statistically significant: Factor 1(12.0407), Factor 2 (1.8322), and Factor 3 (1.2827). Although Factor 4 (0.5047) falls below the conventional threshold, its potential theoretical importance, particularly in capturing ethical dimensions, warrants consideration for retention, especially when corroborated by the scree plot's inflection points. Factors 5 through 26, with minimal or negative eigenvalues, contribute negligibly to variance and are thus excluded. The pronounced dominance of Factor 1 underscores the presence of a robust overarching construct, likely representing general AI literacy, while still allowing for the emergence of complementary, specialized subdimensions. These results justify a parsimonious three-factor solution or a theoretically informed four-factor model for a statistically sound and conceptually coherent foundation for the instrument's structural validity.

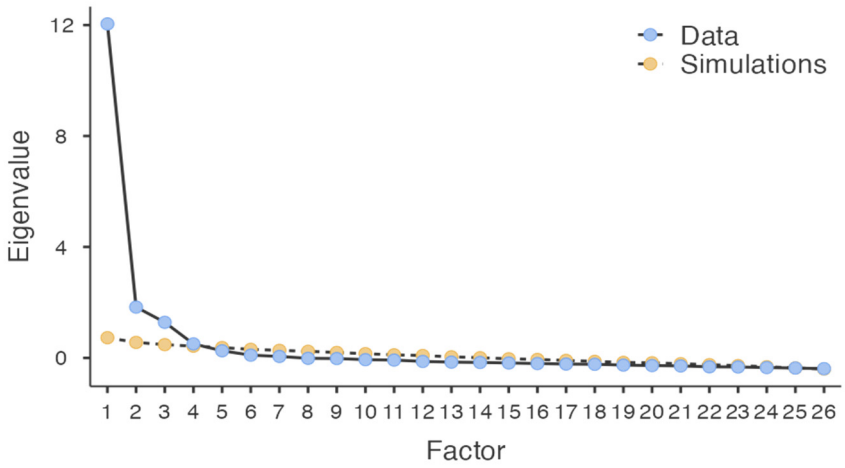

Figure 1. Scree Plot

The scree plot analysis (Figure 1) is a visual evidence of the instrument's underlying structure for its statistical robustness and theoretical coherence. The scree plot and parallel analysis support the four factors. The plot reveals pronounced drops in eigenvalues from the first factor 1 (12.04) to the second (1.83) and third (1.28), indicating that these three factors capture the most substantial and meaningful variance within the data set. Following this sharp decline, the curve flattens noticeably, signaling that subsequent factors contribute minimally to the construct's explanatory power. However, parallel analysis and theoretical relevance support representing the ethics dimension. This outcome is consistent with the conceptual framework underpinning the AI literacy scale, affirming its capacity to represent multiple yet interconnected domains of competency. The scree plot analysis strengthens confidence in the scale's multidimensional design and psychometric integrity.

Table 4. Matrix of rotated factor loadings of the AI Literacy Instrument (Initial)

Item	1	2	3	4	Uniqueness
UND1	0.636			0.316	0.451
UND2	0.720				0.393
UND3	0.754				0.326
UND4	0.705				0.351
UND5	0.693				0.352
UND6	0.659	0.319			0.365
UND7	0.683	0.321			0.389
UND8	0.703	0.384			0.271
UND9	0.698	0.304			0.331
UND10	0.575	0.339			0.454
UAP1		0.726			0.348
UAP2		0.706			0.394
UAP3		0.713			0.346
UAP4		0.768			0.264
UAP5		0.772			0.307
UAP6		0.570			0.648
EVAL1			0.722		0.335
EVAL2	0.317		0.784		0.181
EVAL3	0.313		0.713	0.309	0.267
EVAL4	0.308		0.696		0.294
EVAL5			0.632	0.385	0.347
ETH1	0.397			0.653	0.330
ETH2	0.321		0.319	0.634	0.342
ETH3					0.913
ETH4			0.368	0.713	0.236
ETH5			0.393	0.658	0.342

Note. 'Minimum residual' extraction method was used in combination with a 'varimax' rotation

The exploratory factor analysis (EFA) robustly confirms the four-factor theoretical model underpinning the AI literacy instrument which validates its multidimensional construct and empirical soundness. The results demonstrate that items predominantly load strongly on their designated factors to ensure the conceptual clarity of each dimension (Table 4). Within the Understand domain, items UND1 to UND10 exhibit loading between 0.575 and 0.754, reflecting a solid and consistent representation of foundational AI knowledge. The Use and Apply dimension features meaningful loadings across UAP1 to UAP6, with UAP4 and UAP5 notably achieving the highest coefficient (0.768 and 0.772), underscoring practical application skills. Similarly, the Evaluate and Create subscale aligns well with EVAL2 and stands out through its highest loading (0.784) and lowest uniqueness (0.181), indicating excellent construct fit. Item UAP6 shows high uniqueness (0.648), and since this is a weak shared variance with the underlying construct, the item was removed from the final scale. The AI Ethics factor is well represented by ETH1, ETH2, ETH4 and ETH5 (loadings 0.634-0.713), but ETH3's poor loading and extremely high uniqueness (0.913) suggest a critical need for item revision, but it was decided to remove it in the final scale. Minor cross-loadings exist but are minimal and do not compromise the instrument's theoretical coherence or validity.

The results deliver an empirical validation for the proposed four-dimensional AI literacy structure of Zhou and Schofield (2024). The framework has conceptual rigor and practical applicability in teacher education. Each factor explained a substantive proportion of variance, confirming that the model encapsulates distinct yet complementary domains of AI literacy – knowledge, application, critical evaluation, and ethical engagement. The absence of significant inter-factor correlations affirms the independence of these dimensions, allowing for precise assessment of specific competencies while preserving the integrity of the overarching construct. This structural distinctiveness enhances the instrument's psychometric robustness, ensuring that it can reliably differentiate between various skill sets and knowledge areas. Furthermore, the framework can guide curriculum development, instructional planning and targeted interventions for teacher education programs to systematically cultivate AI readiness. By combining theoretical soundness with actionable insights, the frameworks offer a scalable and adaptable model for preparing educators to thrive in AI-enriched learning environments.

Table 5. Final Matrix of rotated factor loadings (AI Literacy Scale)

Item	1	2	3	4	Uniqueness
UND1	0.623			0.326	0.452
UND2	0.713				0.395
UND3	0.751				0.326
UND4	0.701				0.352
UND5	0.693				0.351
UND6	0.658	0.331			0.361
UND7	0.689	0.304			0.389
UND8	0.705	0.373			0.273
UND9	0.701				0.337
UND10	0.575	0.328			0.456
UAP1		0.758			0.318
UAP2		0.710			0.396
UAP3		0.728			0.337
UAP4	0.315	0.757			0.281
UAP5		0.768			0.317
EVAL1			0.732		0.338
EVAL2	0.310		0.794		0.183
EVAL3	0.306		0.733		0.262
EVAL4			0.709		0.295
EVAL5			0.649	0.354	0.346
ETH1	0.378			0.651	0.321
ETH2			0.343	0.633	0.322
ETH4			0.413	0.660	0.263
ETH5			0.437	0.629	0.346
UND1	0.623			0.326	0.452

Note. 'Minimum residual' extraction method was used in combination with a 'varimax' rotation

The EFA results reveal a clear and statistically solid three-factor structure, aligning precisely with the dimensions Understand AI, Use and Apply AI, and Evaluate and Create with AI (Table 5). Items within each factor demonstrated strong and consistent loadings – UND1 to UND10 range from 0.575 to 0.751 core understanding, UAP1 to UAP5 (with UAP1, UAP4, and UAP5 exceeding .0750) for application, and EVAL1 to EVAL5 (notably EVAL2 at 0.794) for evaluation and creation – accompanied by low uniqueness values, underscoring their strong representation of the intended construct. In contrast, items targeting AI Ethics loaded inconsistently across factors and exhibit moderate to high uniqueness (e.g., ETH5 =0.452), indicating reduced discriminant validity as a distinct dimension. However, these findings confirm that the four identified factors form a coherent, high–integrity framework for assessing AI literacy, while also highlighting the need for conceptual refinement of the ethics component to ensure its distinctive integration within the overall measurement model.

The variance decomposition demonstrates the statistical strength and conceptual coherence of the AI literacy instrument factor structure. Factor 1, with a sum of squared loadings of 5.74, accounts for 23.9% of the total variance, emerging as the dominant dimension and reflecting the central role of core AI understanding within the construct. Factors 2 and 3 contribute an additional 16.1% respectively, bringing the cumulative variance explained by the first three dimensions to 56.1% - a level considered robust and well above the conventional benchmark for social science measurement models. Factor 4, while smaller in magnitude, adds 10.5%, bringing the total explained variance to an impressive 66.6 percent. This cumulative strength shows the empirical adequacy of the four-factor model and also affirms its ability to capture the multifaceted nature of AI literacy among pre-service teachers, ensuring both breadth and depth in measuring competencies across cognitive, practical, evaluative, and ethical domains.

Table 6. Model Fit Measures

RMSEA 90% CI				Model Test		
Lower	Upper	TLI	BIC	χ^2	df	p
0.0587	0.0748	0.932	-625	442	186	<.001

The model fit indices provide persuasive statistical evidence of both the adequacy and robustness of the four-factor structure derived from the EFA, demonstrating its theoretical and practical relevance (Table 6). The Root Mean Square Error of Approximation (RMSEA) value of 0.0665, with a 90 % confidence interval of 0.0587 to 0.0748, falls well within the accepted "reasonable fit" range (<0.08). At the same time, the Tucker–Lewis Index (TLI) of 0.932 exceeds the widely recognized 0.90 threshold, reflecting substantial improvement over the null model. Although the Chi-square statistic is significant (χ^2 = 442, df=186, p <.001), this outcome is expected in large–sample analyses and is best interpreted in conjunction with incremental fit indices, which uniformly affirm model adequacy. The Bayesian Information Criterion (BIC) value of –625 underscores the model's parsimony, balancing explanatory power with simplicity. Taken together,

these fit statistics provide adequate empirical support for the four-dimensional AI literacy framework as a valid and reliable instrument for evaluating pre-service teachers' knowledge, application, critical evaluation, and ethical engagement with AI.

Table 7. Item Reliability Statistics

Item	Mean	SD	Item-rest correlation	Cronbach's α	McDonald's ω
UND1	4.32	0.671	0.648	0.957	0.958
UND2	4.18	0.693	0.657	0.957	0.958
UND3	4.20	0.720	0.700	0.956	0.957
UND4	4.29	0.706	0.728	0.956	0.957
UND5	4.20	0.747	0.733	0.956	0.957
UND6	4.41	0.689	0.745	0.956	0.957
UND7	4.29	0.718	0.682	0.956	0.957
UND8	4.27	0.708	0.786	0.955	0.956
UND9	4.14	0.719	0.739	0.956	0.957
UND10	4.22	0.748	0.701	0.956	0.957
UAP1	4.02	0.810	0.632	0.957	0.958
UAP2	4.06	0.802	0.599	0.957	0.958
UAP3	4.03	0.816	0.634	0.957	0.958
UAP4	3.97	0.820	0.674	0.956	0.958
UAP5	3.98	0.864	0.612	0.957	0.958
EVAL1	4.27	0.787	0.636	0.957	0.958
EVAL2	4.23	0.774	0.733	0.956	0.957
EVAL3	4.20	0.762	0.714	0.956	0.957
EVAL4	4.27	0.771	0.711	0.956	0.957
EVAL5	4.23	0.779	0.686	0.956	0.957
ETH1	4.32	0.710	0.679	0.956	0.957
ETH2	4.37	0.689	0.699	0.956	0.957
ETH4	4.44	0.674	0.711	0.956	0.957
ETH5	4.38	0.685	0.628	0.957	0.958

The item-level analysis provides critical insights into the scale's internal consistency and construct alignment that reveal a predominantly strong item-rest correlations to affirm the coherence of most items with the overall AI literacy construct (Table 7). Several items exhibit particularly solid correlations - UND8 (0.786), UND9 (0.739), UND6 (0.745), and EVAL2(0.733) – highlighting their exemplary contribution to measuring competencies. However, two items, UAP6 (0.350) and ETH3 (0.194) show lower correlations during initial reliability analysis that suggest potential issues such as conceptual ambiguity or unclear wordings that may hinder respondents' consistent interpretation. Notably, UAP6 and ETH3's high standard deviation signal substantial variability and inconsistent responses. Despite these outliers, overall reliability remains exceptionally high, with Cronbach's alpha (0.958) and McDonald's omega (0.959) even after the removal of the two items. These findings show the instrument's robustness while identifying UAP6 and ETH3 as key targets for removal to enhance clarity and psychometric integrity in future iterations. Hence, both UAP6 and ETH3 were removed in the final scale. Thus, retaining 24 items to measure AI literacy among pre-service teachers.

5. Discussion

The integrated reliability and validity evidence suggests that the AI Literacy instrument is theoretically grounded and psychometrically sound, hence serving as a valid instrument to assess the AIL of pre-service teachers. The EFA results illustrate a multidimensional structure that validated the proposed conceptualization of AI Literacy of Zhou and Schofield (2024). Most factors in this study account for a significant proportion of variance in the competencies of the pre-service teachers similar to recent studies (Ning et al., 2025; Zhang et al., 2025). Thus, this four-factor structure framework reflects the distinct constructs of knowledge and understanding, application, evaluation, and AI ethics that contribute to AI Literacy (Biagni, 2024).

Moreover, the high-performing items contribute substantially to the overall coherence of the scale that ensures each construct is represented with clarity and precision. Low-performance items, on the other hand, are positively intended diagnostic bits that can provide insights that could help iterate. This was substantial, but with enough room to grow. Two items were removed in the final instrument to enhance the scale (items UAP6 and ETH3). A testament to the rigor and instrument's adaptability for continued validation and contextualization.

The identified factor structure indicates that the instrument can capture the dimensions of AI literacy among pre-service teachers, with factor loadings indicating strong relationships among observed items and respective latent constructs (Arslankara & Usta, 2024; Salhab, 2024). The strength of the factor loadings confirms that the items are reliable indicators of their intended dimensions, technical understanding, and practical application of the dimensions (Arslankara & Usta, 2024; Biagini, 2024; Laupichler et al., 2023).

The four-factor structure mirrors the intended multidimensionality of a wide range of competencies (technical skills,

cognitive understanding, evaluative judgement, and ethical reasoning). This multidimensional nature is so evident in an AI-integrated educational context when teaching effectiveness cannot exclusively refer to the proficiency of controlling a technical instrument but includes a necessity to evaluate their pedagogical nature and possible consequences.

The evidence positions this instrument as a psychometrically sound tool to assess AI literacy among pre-service teachers in the Philippines to expand the conceptual framework for historically overlooked populations in AI literacy research (Hsu et al., 2025). Likewise, the inclusion of ethics as a distinct and measurable factor addresses a critical gap in existing AI literacy assessments. While technical and cognitive skills enable functional use, ethical competence ensures that AI integration is done in a manner that is responsible, fair, and consistent with professional standards. Given that risk, the ability for educators to measure ethical reasoning on topics like bias detection, data privacy and inclusivity, the instrument empowers educators to mitigate risks and make informed, socially responsible decisions in AI-supported instruction.

5.1 Limitation of the Study

This study is limited by its use of a single institutional sample composed exclusively of pre-service teachers from one state university. While adequate for exploratory factor analysis, the findings may not fully represent other teacher education programs or in-service teaching populations. Data collection relied on self-reported perceptions of AI literacy, which may be influenced by social desirability or varying levels of exposure to AI tools. The study focused on instrument validation through EFA; therefore, further psychometric evaluation such as confirmatory factor analysis (CFA), test–retest reliability, and measurement invariance across demographic groups was not conducted. Additionally, the cross-sectional design restricts the ability to track changes in AI literacy over time. Future research should include larger and more diverse samples, apply additional validation techniques, and explore longitudinal approaches to strengthen the generalizability and robustness of the instrument.

6. Conclusion

Amid the unprecedented challenge of artificial intelligence in the education sector, the lack of research-based measurement tools for AI literacy in teacher preparation programs in the Philippines poses an urgent need for intentional frameworks. The study addresses that gap by developing and validating a 24-item instrument grounded in a four-dimensional framework that includes: Understanding, Use and Application, Evaluation, and Ethics. Psychometric validation confirmed its reliability and soundness and serves as a practical and theoretical scale for assessing AI literacy for Filipino pre-service teachers.

The study offers salient contributions to research. AI literacy as a multidimensional construct integrates cognitive, practical, evaluative, and ethical competencies. It also elucidates actionable diagnostics for teacher education institutions that allow for the identification of strengths and gaps. Policymakers and curriculum designers should embed AI literacy within policy development and professional training of educators.

Although validated in one institution, the scale's theoretical grounding and methodological rigor enhance its transferability across settings. Future research should pursue cross-institutional and cross-cultural validation, longitudinal tracking of competencies, and application among pre-service teachers and educational leaders. By bridging conceptual frameworks with measurable constructs, this instrument advances AI literacy from an aspirational ideal into a pedagogically actionable competency. Teacher education programs should enhance its cuirrculum with a solid foundation for harnessing educators to navigate and lead in AI-driven learning environments.

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Author contributions

J.T. and J.P. were responsible for conceptualization. J.T., C.M.T., J.P. and L.S.P. were responsible for the study design and revision. J.T. and J.P. were responsible for data collection and formal analysis. J.T. drafted the manuscript and C.M.T. and L.S.P. revised it. All authors read and approved the final manuscript. The authors contributed equally to the study.

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