### INVESTIGATING THE DETERMINANTS OF AI LITERACY COMPETENCE IN PRE-SERVICE TEACHERS: A HIGHER EDUCATION CONTEXT

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#### ABSTRACT

Yet, artificial intelligence (AI) is fitted within how we educate, how we teach and how we learn, though its adoption straggle in terms of teacher education. In Pakistan the programs provided at educational institutions are the B.Ed and M.Ed and it is essential for pre service teachers in Pakistan to have AI literacy in order to assist AI integration in the future classrooms. Thus, the aim of this research is to examine the factors affecting the AI literacy proficiency of pre-service teachers, specifically teachers' attitude, and exposure to AI literacy structures and involvement in professional development programs. From 350 pre service teachers recruited in B.Ed and M.Ed programs of higher education institutions of Pakistan, a data was obtained through quantitative research design. The data was examined in order to test hypothesized relationships between AI literacy proficiency and teachers' attitudes through Structural Equation Modeling (SEM). The direct relationship to AI literacy proficiency was displayed for the teacher attitudes but not for the exposure to the AI literacy structures. Also, in the relationship with AI literacy proficiency professional development experiences mediated the teacher attitudes significantly. This signifies that teacher attitudes and sustained professional development to upgrade AI literacy are required. Also, the significance of assertive attitude of teachers towards AI is advised to accentuate by the education institutions and to give into robust, steady professional development programs. Furthermore, it is important to generate contextually appropriate AI literacy frameworks for Pakistan's educational context.

*Keywords:* AI literacy, pre-service teachers, teacher attitudes, professional development, AI frameworks, higher education, Pakistan.

#### INTRODUCTION

The rise of Artificial Intelligence (AI) has made a big impact on a lot of fields, including education, making AI literacy a vital part of modern teaching. AI, which means systems that can resemble human intelligence, has gone from being something far in the future to something we can actually use in classrooms now. It has the capability to change how we teach and learn, helping with problem-solving, creativity, and more personalized learning (Southworth et al., 2023). It's becoming significant to bring AI literacy into education because of this, but it's still a hurdle, particularly in early childhood education (ECE).

As AI is becoming more common, it hasn't been fully unified into ECE yet. Research and curriculum development are way behind what's happening in higher education (Su et al., 2023). One reason for this is that it is still a new field explaining AI literacy to young kids and it needs different disciplines working together to create learning frameworks that are appropriate for their age.



Some big obstacles are indicated by the existing research in trying to bring AI into ECE, like teachers not being properly trained, finite resources, and no clear guidelines for teaching it (Laupichler et al., 2022; Su et al., 2023). The requirement for a more organized strategy to help teachers get the AI knowledge and skills they require is accentuated by these problems.

In childhood education AI literacy means establishing kids to basic AI concepts, like how AI works and how it adjusts into their daily lives (Yi, 2021). Guiding them about AI early on can help them get interested in it and construct up their skills, which could help bridge the digital divide as they move through their education. However, we must vanquish some practical hurdles to make this happen. For instance, Laupichler et al. (2022) say that without clear guidelines, teachers sometimes feel lost and aren't sure how to teach AI concepts properly, which makes it difficult to provide the lessons effectively.

In childhood education, teaching AI has a lot of benefits. AI tools can make learning more interactive and hands-on, letting kids encounter things like machine learning, pattern recognition, and even ethics in a fun way. AI literacy could help balance the playing field, making it easier for kids from diverse backgrounds to understand complex purposes as suggested by Southworth et al. (2023). But this can only happen if we make teaching frameworks that match kids' intellect and emotional development (Ng et al., 2023).

Although a lot of benefits could be brought up by AI literacy, there's still not enough research about how to teach it in childhood education. Most research concentrates on higher education or adult learners, leaving a gap in understanding how to make AI work for young kids (Perchik et al., 2023). Filling this gap requires integration between diverse fields to come up with curriculam that are not only educationally beneficial but also suitable for young learners, both in terms of technology and ethics. Also, we have to discuss affairs like digital equity, teacher training, and making sure schools have the right resources to make AI literacy programs inclusive and sustainable.

Altogether, bringing AI literacy into childhood education is both necessary and full of potential. The hurdles are real, but the opportunity to help young kids evolve crucial thinking, creativity, and tech skills is worth the effort. There's increasing interest in AI literacy research, which is promising, but we need more work to turn these ideas into real, practical solutions. By handling the ongoing obstacles, educators and researchers can help lay the foundation for AI literacy that will prepare kids for an AI-driven future.

Constructing on the gaps in AI literacy at higher education levels, this research intents to look at the key factors affecting AI literacy proficiency among future teachers. The aims of the study are as follows:

#### Research Objectives

1. To evaluate the current level of AI literacy proficiency among pre-service teachers.

2. To examine the influence of teacher attitudes toward AI on AI literacy proficiency.3. To assess the effect of professional development experiences related to AI on AI literacy proficiency.

4. To examine the role of AI literacy frameworks in shaping pre-service teachers' understanding and application of AI concepts.

#### **Research Questions**

To address the study objectives, the following research questions have been formulated to guide the inquiry:

1. What is the current level of AI literacy proficiency among pre-service teachers?

2. How do teacher attitudes toward AI influence their AI literacy competence?

3. What is the impact of professional development experiences related to AI on pre-service teachers' AI literacy competence?

4. How do AI literacy frameworks contribute to the AI literacy competence of pre-service teachers?

The rapid combination of Artificial Intelligence (AI) into education requires a workforce equipped with AI literacy, specifically among pre-service teachers who will shape future learning environments., AI literacy remains underexplored in teacher education, with restricted emphasis on



understanding how attitudes, professional development, and structured frameworks influence proficiency despite its significance. These gaps are addressed by this research by analyzing key predictors of AI literacy proficiency in higher education settings. The research intents to offer insights for developing targeted interventions bv recognizing actionable factors, ultimately enhancing teacher readiness and guaranteeing effective connection of AI into educational practices.

#### Literature Review

The Technology Acceptance Model (TAM) is a well-known framework used to understand how people adapt and use technology, making it a useful tool for studying AI literacy among pre-service teachers. TAM concentrates on how attitudes towards technology and external factors, like training perceived advantages, affect the and acceptance of new technology. It is broadly used because it can be adapted to multiple educational settings (Al-Nuaimi & Al-Emran, 2021; Al-Adwan et al., 2023). TAM volunteers to explore how factors like teacher attitudes, professional development, and AI literacy frameworks all play a role in shaping AI literacy skills in this study.

Multiple key factors are accentuated by TAM, such as the effect of external components like training and the perceived advantages of technology. In main variables of this research, these factors offer valuable insights while TAM particularly emphasizes Perceived Usefulness (PU) and Perceived Ease of Use (PEOU), this research amplify on these ideas by looking at teacher preparedness and the support systems in place for education. For instance, professional development programs can be essential external factors that help preservice teachers feel more ready to work with AI tools (Na et al., 2022). Similarly, on how to integrate AI into teaching, AI literacy frameworks provide clear guidance, addressing any concerns teachers may have.

This research also understands how teachers' attitudes toward technology fit with TAM's view that assertive attitudes influence the adoption and use of new technologies. Research has shown that when teachers have a good attitude towards technology, they are more likely to try out and include new tools into their teaching (Alfadda & Mahdi, 2021; Liu & Ma, 2024).

However, for not fully considering factors like institutional contexts and cultural differences, TAM has been critically condemned (Aburbeian et al., 2022). This study responds to this criticism by applying TAM to the particular environment of teacher education, identifying how both personal and organizational factors can influence technology adoption. This research provides a more comprehensive understanding of AI literacy and can help develop practical approaches to improve technology adoption in higher education by using TAM.

# Teacher Attitudes and AI Literacy Competence

Teacher attitudes toward Artificial Intelligence (AI) are critical in shaping their potential to understand and use AI effectively. When teachers have an assertive view of AI, they are more likely to analyze AI-based tools, which help them consider how these tools can be useful and appropriate in education (Boscardin et al., 2024). Teachers who have a good perception of AI are more willing to try out these tools, which helps them improve their AI literacy and proficiency as displayed by this research (Cardon et al., 2023). On the other hand, negative attitudes, such as concerns about ethical issues or fears that AI may replace teachers, can make it difficult for AI to be adopted (Zhao et al., 2022). While Wang et al. (2024) argue that positive attitudes are a strong predictor of technology adoption, they also address that attitudes alone aren't enough to construct proficiency unless there are real learning opportunities to go along with them. To investigate this further, this study proposes the following hypothesis:

# H1: Teacher attitudes toward AI positively influence AI literacy competence.

### Exposure to AI Literacy Frameworks and AI Literacy Competence

In education, involving AI literacy frameworks is becoming more and more acknowledged as a significant step in helping



educators develop AI literacy skills. Clear guidelines and resources are provided by these frameworks, making it easier for teachers to understand complex AI concepts and include them into their teaching practices (Southworth et al., 2023). According to Zhao et al. (2022), having access to AI frameworks not only helps teachers hold onto the basic ideas behind AI, but also boosts their confidence, which is key to building proficiency. However, Cetindamar et al. (2022) warn that the successfulness of these frameworks relies on how relevant, accessible, and well-aligned they are with the teachers' particular professional requirements. Simply disclosing teachers to these frameworks isn't enough; they also need additional support, like training and ongoing guidance. Frameworks are still an essential resource for educators even with these hurdles, which lead to the following hypothesis:

H2: Exposure to AI literacy frameworks positively influences AI literacy competence. Teacher Attitudes and Participation in Professional Development Programs

Teachers' attitude towards AI plays a huge role in how involved they are in professional development programs. Those with an assertive attitude are more likely to see these programs as valuable chance to improve their knowledge and skills (Nazaretsky et al., 2022). On the other hand, teachers who have a negative or indifferent view of AI may see professional development as unessential, which can restrict their participation (Kong et al., 2021). Professional development programs are structured to help teachers build technical skills, their success hugely relies on the teachers' motivation and willingness to learn as said by Ng et al. (2023). Constructing AI literacy among educators, professional development programs are essential as they provide hands-on training, theoretical knowledge, and opportunities for reflection (Kong et al., 2023). These programs help fill knowledge gaps, boost confidence, and allow teachers to effectively include AI tools into their teaching practices (Nazaretsky et al., 2022). However, their effectiveness can be mitigated by the obstacles like finite resources, lack of institutional support, and differences in program quality (Su et al., 2023).

Because of this, the following hypothesis has been proposed:

H3: Teachers having Professional Development experiences mediate the relationship between their attitude toward AI and AI literacy Competence.



#### Figure 1 Conceptual Framework

#### Methodology

This research aimed to examine the factors that encourage AI literacy proficiency among pre-service teachers, with a focus on teacher attitudes, exposure to AI literacy frameworks, and professional development experiences. For this research, a purposive sampling technique was used to choose participants. This method was selected because it permits researchers to pick participants based on particular characteristics that are essential to the study's aims (Thomas, 2022). The research focused on pre-service teachers enrolled in Bachelor of Education (B.Ed) and



Master of Education (M.Ed) programs in universities in Karachi that include Artificial Intelligence (AI) in their curriculum. As suggested by Ringle et al. (2023), a total of 200 participants were chosen to guarantee enough data for statistical analysis and to meet the needs for Structural Equation Modeling (SEM).

The research followed a quantitative design, with a post-positivist philosophical strategy. Post-positivism acknowledges that while an objective reality exists, human understanding of it is always imperfect (Pandey & Pandey, 2021). This strategy permitted for objective measurement of AI literacy proficiency and its determinants, while also recognizing the complexity of fully understanding these relationships. The research aimed to measure teacher attitudes, exposure to AI frameworks, professional development, and their effects on AI literacy proficiency.

Data was obtained using a structured questionnaire based on a five-point Likert scale. The Likert scale was selected to quantify the attitudes and perspectives of participants toward AI literacy, offering a clear and systematic way to assess the data (Mishra & Alok, 2022). The questionnaire was structured based on previous research on literacy and teacher professional AI development, guaranteeing its relevance and validity (Pandey & Pandey, 2021). The questions measured four key variables: teacher attitudes, exposure to AI literacy frameworks, professional development experiences, and AI literacy proficiency.

The sample involved both male and female pre-service teachers enrolled in B.Ed and M.Ed programs at universities in Karachi that teach AI as part of their curriculum. The inclusion criteria needed participants to be enrolled in these specific programs and to have experience with AI in their studies. Preservice teachers who were not enrolled in AIincorporated programs or had little exposure to AI concepts were eliminated. This strategy guaranteed the data was relevant and concentrated on the research objectives related to AI literacy in pre-service teachers. From Karachi, Lahore, and Islamabad a total of 350 responses were collected, which are the largest cities in Pakistan.

By using Structural Equation Modeling (SEM) with Smart PLS, the data was examined. SEM was selected because it permits for the analysis of complex relationships between observed and hidden variables, making it a useful tool for understanding causal relationships in social science research (Ringle et al., 2023). This study was permitted by this method to investigate various relationships at once, offering a comprehensive understanding of the factors affecting AI literacy proficiency.

A significant part of this research was ethical considerations. Informed consent was acquired from all participants, guaranteeing they understood the research's aim, the methods included, and their right to privacy. Participants were guaranteed that their responses would be kept anonymous and used only for research purposes. Ethical approval was granted by the relevant institutional review boards, guaranteeing the study followed ethical guidelines for research with human participants. The research also sticked to data protection rules and avoided plagiarism, guaranteeing the integrity and originality of the research (Mishra & Alok, 2022).

Table 1 Respondent Profile			
Category	Subcategory	Frequency	Percentage (%)
Gender	Male	140	40.0%
	Female	210	60.0%
Age	20-25	105	30.0%
	26-30	175	50.0%
	31-35	70	20.0%
Programs	B.Ed	140	40.0%





Category	Subcategory	Frequency	Percentage (%)
	M.Ed	210	60.0%
Cities	Karachi	160	45.7%
	Lahore	120	34.3%
	Islamabad	70	20.0%
Total		350	100.0%

In Table 1, the respondent profile demonstrates a total of 350 participants, with 60% females and 40% males. The largest group of respondents are disclosed by the age distribution (50%) is in the 26–30 age range, followed by those aged 20–25 years (30%), and then the 31–35 years group (20%). In terms of academic programs, 60% of the

participants are from the M.Ed program, while 40% are from the B.Ed program. Geographically, the majority of participants are from Karachi (45.7%), followed by Lahore (34.3%), and Islamabad (20%). This diverse sample offers a wide horizon of AI literacy competence across various demographics and academic backgrounds.

#### Table 2 Outer Loadings

	AI Literac	y Exposure	to AI	Professional	Development	Teacher
	Competence	Literacy Fr	rameworks	Experiences		Attitude
AILC1	0.729					
AILC2	0.810					
AILC3	0.847					
AILC4	0.819					
AILC5	0.807					
EAILF1		0.777				
EAILF2		0.776				
EAILF3		0.813				
EAILF4		0.851	stitute for Excellence in E	lucation & Research		
EAILF5		0.932				
PDE1				0.730		
PDE2				0.879		
PDE3				0.801		
PDE4				0.769		
PDE5				0.810		
TA1						0.783
TA2						0.816
TA3						0.874

Table 2 demonstrates the outer loadings of items used to calculate four key constructs: AI Literacy Proficiency, Exposure to AI Literacy Frameworks, Professional Development Experiences, and Teacher Attitude. All loadings are above the suggested threshold of 0.7, which shows strong dependency and convergent validity for the items. For AI Literacy Competence, the loadings range from 0.729 to 0.847, indicating a good fit between the items and the construct. The dependency of Exposure to AI Literacy Frameworks is also ensured, with loadings ranging from 0.776 to 0.932. The loadings for Professional Development Experiences (0.730 to 0.879) and Teacher Attitude (0.783 to 0.874) are also within an acceptable range. The validity of the measurement model is confirmed by these outcomes



#### Table 3 Model Fit

	Saturated Model	Estimated Model
SRMR	0.706	0.721
Chi-Square	2.432	2.145
NFI	0.974	0.967

Table 3 confirms an excellent model fit. The SRMR values of 0.706 and 0.721 are well below the suggested threshold of 0.08, showing very low remaining variation. The Chi-Square ratios (2.432 and 2.145) also lies

within the acceptable range of 1 to 3. Furthermore, the high NFI values of 0.974 and 0.967 displays a strong fit between the theoretical model and the empirical data.

#### Table 4 Convergent Reliability

		Composite	
	Cronbach's Alpha	Reliability	Average Variance Extracted
AI Literacy Competence	0.863	0.871	0.645
Exposure to AI Literacy Framework	0.888	0.906	0.692
Professional Development Experiences	0.858	0.864	0.639
Teacher Attitude	0.769	0.806	0.681

Table 4 demonstrates the reliability metrics for the constructs being acknowledged. All constructs show acceptable levels of reliability and validity. Internal consistency is confirmed by Cronbach's Alpha values ranging from 0.769 to 0.888, which are above the minimum threshold of 0.7. The Composite Reliability (CR) values lie between 0.806 and 0.906, surpassing the suggested cutoff of 0.7, further confirming the reliability of the constructs. The Average Variance Extracted (AVE) values range from 0.639 to 0.692, which are above the 0.5 threshold, displaying sufficient convergent validity. These results confirm the reliability and convergent validity of the measurement model.

#### Table 5 Discriminant Validity - H

		Exposure to AI	Professional	
	AI Literacy	Literacy	Development	Teacher
	Competence	Framework	Experiences	Attitude
AI Literacy Competence				
Exposure to AI Literacy Framework	0.668			
Professional Development Experiences	0.860	0.837		
Teacher Attitude	0.586	0.806	0.785	

Table 5 demonstrates the results of the Heterotrait-Monotrait Ratio (HTMT), which is used to evaluate the discriminant validity of the constructs. HTMT values below 0.85 shows that the constructs are different from one another. The values shown in the table are all below this threshold, supporting the idea that the constructs—AI Literacy

Competence, Exposure to AI Literacy Frameworks, Professional Development Experiences, and Teacher Attitude—are sufficiently separate. We can confirm that the constructs do not overlap by using HTMT, guaranteeing the validity of the measurement model and clearly differentiating each construct.

#### Table 6 Bootstrapping - Path Coefficients

	Original Sample (o)	T Statistics	P Values	Remarks
H1: Teacher's Attitude -> AI Literacy Competence	0.371	2.307	0.021	Accepted
H2: Exposure to AI Literacy Framework -> AI				
Literacy Competence	0.193	0.612	0.541	Rejected
H3: Teacher Attitude -> Professional Development				
Experiences -> AI Literacy Competence	0.500	3.856	0.000	Accepted

To assess the relationships between the the model, constructs in we used bootstrapping to evaluate the path coefficients and their importance. Essential insights were disclosed by the results from the bootstrapping analysis. First, for Hypothesis 1 (H1), we found that teacher attitudes have a visible positive effect on AI literacy competence (p = 0.021, path coefficient = 0.371). This means that teachers' attitudes toward AI are critical for their AI literacy, confirming our hypothesis that positive attitudes conduct to higher AI literacy levels among educators.

In contrast, Hypothesis 2 (H2) showed that exposure to AI literacy frameworks does not have an essential direct impact on AI literacy competence (p = 0.541). This recommends that simply exposing teachers to AI frameworks alone will not essentially improve their AI literacy.

Lastly, Hypothesis 3 (H3) revealed that professional development experiences mediate the relationship between teacher attitudes and AI literacy competence (p = 0.000, path coefficient = 0.500). This means that professional development programs play a vital role in bridging the gap between teacher attitudes and AI literacy.

Overall, it is displayed that teacher attitudes directly encourages AI literacy proficiency. by these results. However, it is vital to effectively improve AI literacy among pre-service teachers by structured professional development programs. On the other hand, barely exposing teachers to AI frameworks does not seem to have a visible effect, accentuating the requirement for more detailed approaches for developing AI literacy in educators.

#### Discussion

A vital contribution to the literature on AI literacy is made by the findings from this research, specifically within the context of Pakistani higher education institutions providing B.Ed and M.Ed programs to preservice teachers. Our results portray that teacher attitudes, exposure to AI literacy frameworks, and professional development experiences all interact with AI literacy competence.

In support of Hypothesis 1 (H1), we found that teacher attitudes have a strong direct effect on AI literacy proficiency. This finding lines up with the previous research (Cardon et al., 2023; Boscardin et al., 2024), accentuating the significance of assertive attitudes toward the adoption and use of AI tools in the classroom. Teachers with affirmative attitudes are more likely to experiment with and include AI tools into their teaching, which elevate their AI literacy. However, while assertive attitudes create an initial exposure to AI, factors such as a lack of institutional support and inadequate hands-on training opportunities may explain why attitudes alone do not always conduct to higher AI literacy proficiency.

In the case of Hypothesis 2 (H2), while vital in theory we found that exposure to AI literacy frameworks did not have a significant direct effect on AI literacy proficiency. These finding contrasts with Southworth et al. (2023), who debates that structured AI frameworks. can emphasize educators' understanding and confidence. In our context, AI frameworks may exist, but they might not be altered to the local context or the particular requirements meet of effectiveness such educators. The of frameworks relies on their relevance to teachers' professional realities as accentuated by Cetindamar et al. (2022). AI literacy frameworks are finite, exposure alone may not be enough. Without additional support like training, mentorship, and practical application opportunities, in Pakistan, the effect of these frameworks could be minimal.



Strong support was found for Hypothesis 3 (H3), which advise that professional mediate development experiences the relationship between teacher attitudes and AI literacy proficiency. This is consistent with previous studies, the crucial role of professional development programs in creating AI literacy is accentuated bv (Nazaretsky et al., 2022; Kong et al., 2023). Such programs are vital to fill gaps in teachers' knowledge and skills in the Pakistani educational context. Hands-on experience, integrated with confidencebuilding, is critical for incorporating AI into practices, and professional teaching development programs offer this. However, these programs can encounter obstacles such as finite resources, diverse program quality, and inadequate institutional support as noted by Su et al. (2023). Professional development programs are most effective when teachers have assertive attitudes toward AI as recommended by our findings, accentuating the requirement for ongoing, targeted professional development to encourage AI literacy.

#### **Conclusion and Future Directions**

The factors that encourage AI literacy proficiency among pre-service teachers in Pakistani higher education institutions providing B.Ed and M.Ed programs were investigated by this research. It was disclosed by these findings that, on its own exposure to AI literacy frameworks has a finite impact on emphasising AI literacy. However, in improving AI literacy, teacher attitudes and professional development experiences play a vital role. The outcomes show that assertive teacher attitudes directly encourage AI literacy proficiency, and professional development programs serve as a key mediator in this relationship. In Pakistan, these findings are specifically significant, where access to AI resources and training is still developing, and the incorporation of AI into educational practices is in its initial stages.

The educational policy makers and administrators are advised to concentrate on promoting assertive teacher attitudes towards AI by this research. For the incorporation of AI in education they should make a supportive and motivating environment. The significance of professional development programs that equip teachers with the necessary skills and confidence to integrate AI into their teaching methods must also be acknowledged by the managers. These programs should be more than just theoretical; they should provide hands-on experiences that permit teachers to implement what they learn in real classroom settings.

Moreover, educational institutions should give into the development of AI literacy structures that are pertinent to the local context. Ongoing support through mentorship and consistent training in using these frameworks is crucial to guarantee their successful execution These frameworks should line up with existing teaching practices and address the distinctive obstacles of the Pakistani education system. The research advises for an extensive approach to AI literacy, including the promotion of positive teacher attitudes, providing rich professional development opportunities, and guaranteeing that AI literacy tools are comprehensible and suited to the local educational environment.

In Pakistan's education systems there should be a precise concentration on the systemic obstacles by the future research, such as finite access to resources, unsteady teacher training, and a lack of institutional support for AI incorporation. Studies should also examine the generation of AI literacy structures altered to local needs. Moreover, this study could examine the long-term impact of professional development programs on AI proficiency and teaching practices. Understanding how AI tools can he productively connected into various while educational settings, considering cultural and infrastructural limitations, will be vital to guarantee the sustainable and equitable use of AI in education.



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