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# Mapping AI Literacy Among Punjab's Teachers Using Structural Equation Modelling

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ABSTRACT

As smart technology propels the advancement of various sectors, artificial intelligence (AI) has emerged as a pivotal driver of innovation and transformation in education. For educators, proficiency in AI and the enhancement of AI literacy are crucial for professional development. This research investigates the interrelationships among different facets of AI literacy to augment classroom teaching efficacy and foster the adoption of AI literacy. An analysis of 1013 survey responses forms the basis of our findings, concentrating on educators' AI literacy levels, encompassing Knowing and Understanding AI (KUAI), Applying AI (AAI), Evaluating AI Application (EAIA), and AI Ethics (AIE). The results indicate that AAI significantly and positively influences the other three dimensions. Consequently, it is imperative for governments to implement measures aimed at enhancing teachers' AI literacy (Bjola, 2022). To facilitate this development, diverse curricula, comprehensive content, innovative methods, and practical resources for specialized training must be provided, positioning AI literacy as a critical enabler for the sustainable professional growth of educators.:

## Introduction

Artificial intelligence (AI) has become a fundamental component of contemporary life, necessitating the effective preparation of teachers to utilize intelligent technologies in educational settings. Since its inception in the 1950s, AI's role in education has transformed, leading to the development of intelligent machines and algorithms that adapt and simulate human intelligence. AI encompasses the science and technology of formulating theories, methods, techniques, and application systems that emulate and extend human intelligence, often functioning without a predetermined logical sequence or algorithm (Holmes, 2022).

Historically, Information and Communication Technology (ICT) courses have been offered to enhance teacher education, operating under the assumption that equipping teachers with the requisite knowledge and skills at the outset will enable them to meet course requirements and seamlessly integrate AI technology into their teaching practices (Raisch and Krakowski, 2021). AI technology is a significant catalyst for educational reform, profoundly impacting teachers' professional development (Holmes, 2022; Zhang et al., 2021). However, AI education courses and training opportunities are more accessible to students than to teachers (Zhang et al., 2021). Therefore, it is imperative to understand AI literacy to develop teachers' capabilities effectively (Barak, 2017).

To address this gap, this study investigates the various dimensions of AI literacy among teachers, including Knowing and Understanding AI (KUAI), Applying AI (AAI), Evaluating AI Application (EAIA), and AI Ethics (AIE) (Hu & Xu, 2021). By examining these dimensions, the research aims to enhance classroom teaching effectiveness and promote the widespread adoption of AI literacy among educators. The findings underscore

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the necessity for governmental initiatives to support AI literacy development, emphasizing the importance of diverse curricula, comprehensive content, innovative methods, and practical resources for specialized training (Sharifi et al., 2021). This approach positions AI literacy as a critical enabler for the sustainable professional growth of teachers in Punjab, India and beyond.

## Literature Review

As per the available review of literature, the AI literacy trends observed in Punjab present unique insights when juxtaposed with global patterns. Prima facia, Punjab's educators show a moderate level of AI literacy across dimensions like Knowing and Understanding AI (KUAI), Applying AI (AAI), Evaluating AI Applications (EAIA), and AI Ethics (AIE), these trends highlight regional strengths and gaps. For instance, the emphasis on foundational AI concepts aligns with global efforts in developed regions, such as the US and Europe, where AI literacy programs integrate advanced computational thinking and machine learning applications into teacher training. However, Punjab lags in providing robust infrastructure and widespread access to AI literacy courses, akin to challenges faced by developing regions like parts of Africa and Southeast Asia. Addressing these disparities requires adopting global best practices, such as introducing scalable AI education models and enhancing teacher training frameworks, thus positioning Punjab as a case study in addressing AI literacy challenges in developing educational ecosystems.

### AI Literacy

AI literacy represents a multifaceted skill set essential for navigating the increasingly complex landscape shaped by artificial intelligence (AI) technologies. It merges elements of technological proficiency with critical literacy, enabling individuals to comprehend, evaluate, and engage with AI concepts across various domains (Fraillon et al., 2013). Within this framework, Ng et al. delineate four foundational dimensions of AI literacy, each serving as a pillar for comprehensive understanding and application. The first dimension involves grasping fundamental AI concepts, but not limited to machine learning, neural networks, and algorithms. This foundational knowledge equips individuals with a basic understanding of how AI systems operate, laying the groundwork for more advanced comprehension and practical application. It serves as a cornerstone for building proficiency in AI-related fields and facilitates effective communication about AI concepts and technologies. Building upon this foundational understanding, the second dimension emphasizes the practical application of AI concepts. Here, individuals learn to leverage AI tools, programming languages, and frameworks to develop solutions for real-world problems. This hands-on experience enhances their ability to translate theoretical knowledge into actionable insights, fostering creativity and innovation in AI-driven endeavours. Critical evaluation and engagement constitute the third dimension of AI literacy, wherein individuals learn to assess the reliability, accuracy, and societal implications of AI technologies (Ng et al., 2018). This involves discerning potential biases, ethical considerations, and unintended consequences associated with AI systems. By cultivating a critical mindset, individuals can navigate the ethical and societal complexities inherent in AI adoption, contributing to the responsible development and deployment of AI technologies.

### Knowing and Understanding AI

Understanding AI's foundational concepts is crucial for teachers as AI technologies increasingly integrate into education. Teachers need to grasp core ideas such as big data, which involves managing and analyzing vast amounts of information to make informed decisions, and computational thinking, which includes solving problems using fundamental computer science principles like logical analysis and algorithm design. Additionally, comprehending machine learning is essential as it involves how algorithms learn from data to make predictions or decisions. This theoretical knowledge allows teachers to critically evaluate and effectively use AI tools in their classrooms, ensuring they are not misapplied or over-relied upon without understanding their limitations and ethical implications (Coghlan et al., 2021). A solid understanding of AI principles enhances teachers' confidence and self-perception, making them more willing to adopt and integrate AI-driven innovations in their teaching practices. This readiness is crucial for their professional growth and the ability to lead educational advancements. Prioritizing AI literacy through comprehensive training and ongoing professional development ensures that teachers are well-equipped to navigate and leverage AI-enhanced educational environments. This not only benefits their careers but also better prepares students for a future where AI plays a significant role in various aspects of life and work.

### Applying AI

Educating teachers on the application of AI concepts in various contexts is essential for preparing both educators and students to navigate an increasingly AI-driven world. AI literacy courses that cover machine learning applications aim not only to equip teachers with the skills to integrate AI into their teaching practices but also to foster a broader understanding of how AI can be adapted across different careers (Zhang et al., 2021). These courses also address AI-related ethical issues, emphasizing the importance of using AI responsibly and considering its impact on society. By learning how to apply AI concepts, teachers can help their students develop critical thinking skills and a deeper understanding of the technologies

that shape their lives. Human-centered considerations are a critical component of AI education, focusing on the ethical use of AI concepts and applications. Teachers often struggle to guide their students in using AI effectively due to challenges in analyzing data efficiently or integrating AI into instructional design. Applying AI accurately and correctly in the classroom requires teachers to move beyond theoretical knowledge to practical implementation. Teachers must develop the ability to analyze data and understand how AI can be integrated into various subjects and instructional strategies. This involves creating lesson plans that incorporate AI tools and methodologies, facilitating hands-on experiences where students can engage with AI technologies directly (Hepworth and Smith, 2008). By mastering the application of AI, teachers can provide their students with the skills needed to thrive in a world where AI is prevalent, ensuring that they are not only consumers of AI technologies but also informed and ethical users.

### Evaluating AI Application

Evaluating AI applications is a more complex task than simply applying AI, as it requires teachers to possess critical competencies and the ability to collaborate effectively with AI technologies. To do this, teachers need a deep understanding of the scientific and technological principles underlying AI, which can be developed through continuous and updated curricula. Such knowledge enables teachers to critically assess the efficacy, ethical implications, and potential biases of AI tools. By evaluating AI applications, teachers can better inform their instructional practices, support student learning, and find innovative ways to incorporate AI concepts into their teaching (McBride, 2015). This rigorous evaluation process is essential not only for ensuring the appropriate and ethical use of AI in education but also for enhancing teachers' motivation and interest in teaching with AI, as they become more confident and proficient in leveraging these technologies to create more effective and engaging learning experiences.

## Relationships among Key Concepts

### Relationship between Knowing and Understanding AI and Evaluating AI Application

Understanding AI concepts is essential for educators to effectively evaluate AI applications in education. Concepts such as deep learning, machine learning, and block chain form the bedrock of AI technologies, influencing their functionalities and potential uses in teaching and learning. AI literacy courses play a crucial role in equipping teachers with both theoretical knowledge and practical skills necessary for evaluating AI tools and platforms. By integrating these courses into professional development, educators gain the ability to critically assess AI solutions, understand their educational implications, and navigate ethical considerations (Chen et al., 2022). Additionally, access to supportive learning artifacts like advanced hardware and software enhances teachers' engagement with AI, fostering a deeper understanding and motivation to explore AI's educational potential. This foundational understanding empowers educators to harness AI effectively in enhancing student learning experiences and preparing them for a digitally-driven future (Ng et al., 2021).

### Relationships among Applying AI with Other Aspects

Applying AI concepts and their practical implementation across various educational contexts are fundamental aspects of AI literacy for teachers. These courses are designed not only to impart foundational AI skills but also to enable educators to integrate AI confidently into their teaching practices. By mastering AI applications, teachers can initiate critical discussions on its educational implications, actively use AI tools to innovate their instructional methods, and thereby enhance student learning experiences. This practical application of AI also contributes to teachers' personal empowerment, allowing them greater control over their professional development and adaptability in a technology-driven landscape (Appova et al., 2022). Moreover, the application of AI directly influences other dimensions of AI literacy, such as Knowing and Understanding AI (KUAI), where hands-on experience deepens theoretical understanding, and Evaluating AI Application (EAIA) and AI Ethics (AIE), where practical insights inform ethical considerations in AI use. This holistic approach equips educators to navigate the complexities of AI integration effectively, fostering a dynamic educational environment conducive to technological advancement and ethical practice (Long and Magerko, 2020).

### Correlations among AI Ethics, Knowing and Understanding AI, and Evaluating AI Application

AI Ethics, Knowing and Understanding AI, and Evaluating AI Application are interconnected dimensions crucial for educators navigating AI in educational settings. AI's impact on decision-making underscores the importance of addressing its ethical implications. Teachers must be adept at recognizing and mitigating potential societal harms stemming from AI, including biases in algorithms and privacy infringements. By incorporating AI ethics into their pedagogical practices, educators can ensure responsible and equitable use of AI tools (Burns et al., 2013). This involves fostering a learning environment where AI applications are deployed reliably and transparently, prioritizing principles of fairness, accountability, and respect for individual privacy. Educators play a pivotal role in shaping students' understanding of AI's ethical considerations, preparing them to navigate an increasingly

AI-driven world with awareness and integrity.

## Hypothesis

AI literacy courses aim not only to enhance teachers' conceptual understanding and literacy skills but also to equip them with practical abilities to apply AI effectively. By mastering AI fundamentals, educators gain confidence to integrate AI into their daily teaching practices, fostering student development and sharing innovative ideas with peers. As teachers become proficient in AI, they naturally engage in critical discussions, leverage AI to transform instructional methods, and experience personal empowerment by gaining greater control over their professional lives. Through exposure to AI concepts and assessments, educators deepen their understanding of AI's functionalities and ethical implications, enhancing their overall AI literacy. Therefore, applying AI is pivotal in influencing Knowing and Understanding AI (KUAI), Evaluating AI Application (EAIA), and AI Ethics (AIE), forming integral components of comprehensive AI literacy development among educators.

### *Hypothesis 1*

Applying AI has a positive effect on Knowing and Understanding AI (KUAI).

### *Hypothesis 2*

Applying AI has a positive effect on Evaluating AI Application (EAIA).

### *Hypothesis 3*

Applying AI has a positive effect on AI Ethics (AIE).

## Methodology

Data for this study were collected through a survey administered over the course of one month in 2023. Initially, 1246 questionnaires were distributed to teachers across Punjab, India. Following the exclusion of 59 questionnaires due to inconsistencies and extreme responses, 1187 valid questionnaires remained. To ensure balanced representation from schools in the districts of Amritsar, Jalandhar, and Bathinda, a random trimming method was applied, resulting in a final sample size of 1012 questionnaires. The participants included primary, secondary, and a few higher education teachers, with a demographic distribution of 70.5% female and 29.5% male (high ratio of females in schools). The survey comprised 20 items organized into four dimensions: Knowing and Understanding AI (KUAI), Applying AI (AAI), Evaluating AI Application (EAIA), and AI Ethics (AIE). The KUAI dimension assessed teachers' fundamental understanding and knowledge of AI concepts, while the AAI dimension evaluated the integration of AI into their teaching practices. The EAIA dimension measured teachers' ability to assess the effectiveness and appropriateness of AI applications, and the AIE dimension focused on the ethical considerations and implications of AI usage in educational settings. Each item was rated on a Likert scale from one to five, indicating varying levels of AI literacy. The study employed Structural Equation Modeling (SEM) as the primary analytical technique due to its ability to manage complex relationships among multiple variables and simultaneously validate hypotheses. Before SEM, Exploratory Factor Analysis (EFA) with Oblimin rotation confirmed the factorial structure and adequacy of the measurement model. The Kaiser-Meyer-Olkin (KMO) measure was 0.968, and Bartlett's test of sphericity was significant ($\chi2=26,500.320$, $p<0.05$), indicating suitability for factor analysis. Confirmatory Factor Analysis (CFA) using IBM® SPSS® Amos software (version 24) validated the measurement model. The structural model was then analyzed to explore the relationships between latent variables (KUAI, AAI, EAIA, and AIE) and their observed variables. Path coefficients were estimated, and model fit was assessed using several indices, including chi-square, comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA), all of which indicated a good fit of the model to the data.

## Participants

Participants included teachers from various educational stages: 57.8% (n = 585) from primary education, 41.7% (n = 422) from secondary education, and 0.5% (n = 5) from higher education. All participants were educators with at least one year of teaching experience in formal schools from grade one to twelve in various schools of Punjab. A systematic random sampling technique ensured representation across different subjects. The study adhered to ethical research guidelines, and all respondents participated voluntarily.

The demographic breakdown of participants **(see Table 1)** showed a majority of female teachers, reflecting the gender distribution typical in the education sector. The distribution across primary and secondary educational stages was nearly balanced, with a smaller proportion from higher education. Geographically, participation decreased with proximity to urban centers. The distribution by educational background and job title mirrored a pyramid structure, with fewer participants having higher educational qualifications and senior job titles. Participant ages were evenly spread across four age groups.

# Results

### *Descriptive and Correlation Statistics*

**Table 2** presents the means, standard deviations, and correlations among the key constructs. According to Hu and Bentler (1999), the statistical assumptions for structural equation modelling analysis were met in this dataset. Mean ratings for Knowing and Understanding AI (KUAI), Applying

**Table 1:** Demographics, Sex, Educational, Location and other details of the respondents

| *Demographics* | *Level* | *Sample Size* | *Percentage* | *Total* |
|---|---|---|---|---|
| Sex | Male | 298 | 29.5% | 1012 |
| | Female | 714 | 70.5% | |
| Educational Stage | Primary | 585 | 57.8% | 1012 |
| | Secondary | 422 | 41.7% | |
| | Higher Education | 5 | 0.5% | |
| Location | Rural | 511 | 50.5% | 1012 |
| | Suburban | 333 | 32.9% | |
| | Urban | 168 | 16.6% | |
| Educational Background | Below Bachelor | 187 | 18.5% | 1012 |
| | Bachelor's Degree | 745 | 73.6% | |
| | Postgraduate | 80 | 7.9% | |
| Age | ≤30 | 206 | 20.4% | 1012 |
| | 31–40 | 273 | 27.0% | |
| | 41–50 | 329 | 32.5% | |
| | ≥51 | 204 | 20.1% | |
| Job Title | Beginner | 410 | 40.5% | 1012 |
| | Intermediate | 400 | 39.5% | |
| | Deputy Senior | 196 | 19.4% | |
| | Senior | 6 | 0.6% | |

**Table 2:** Means, Standard Deviations, and Correlations of the Key Constructs

| | *Mean* | *SD* | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Sex | -- | -- | 1 | | | | | | | |
| 2. Location | -- | -- | -0.066* | 1 | | | | | | |
| 3. Educational Background | -- | -- | -0.223** | 0.307** | 1 | | | | | |
| 4. Age | -- | -- | 0.330** | -0.228** | -0.514** | 1 | | | | |
| 5. KUAI | 3.64 | 0.92 | -0.038 | 0.094** | 0.097** | -0.140** | 1 | | | |
| 6. AAI | 3.46 | 0.94 | -0.024 | 0.108** | 0.101** | -0.184** | 0.773** | 1 | | |
| 7. EAIA | 3.45 | 0.92 | -0.023 | 0.077* | 0.098** | -0.188** | 0.725** | 0.894** | 1 | |
| 8. AIE | 4.01 | 0.93 | -0.073* | 0.018 | 0.074* | -0.070* | 0.561** | 0.506** | 0.513** | 1 |

*Note: **p<0.01; *p<0.05. SD, standard deviation; KUAI, Knowing & Understanding AI; AAI, Applying AI; EAIA, Evaluating AI Application; AIE, AI Ethics.*

**Table 3:** Statistical Summary of Reliability and Validity of the Questionnaire (Continued)

| *Constructs* | *Items* | *Mean (SD)* | *Cronbach's α* | *Factor Loading* | *CR* | *AVE* |
|---|---|---|---|---|---|---|
| Demographics | 6 | NA | NA | NA | NA | NA |
| Knowing and Understanding AI | 5 | 3.636 (1.025) | 0.936 | 0.707–0.871 | 0.938 | 0.660 |
| Applying AI | 5 | 3.457 (1.000) | 0.966 | 0.807–0.867 | 0.966 | 0.695 |
| Evaluating AI Application | 5 | 3.449 (0.971) | 0.972 | 0.825–0.905 | 0.976 | 0.748 |
| AI Ethics | 5 | 4.007 (0.985) | 0.969 | 0.835–0.924 | 0.968 | 0.793 |

***Note:*** *CR = Composite Reliability; AVE = Average Variance Extracted. Factor loadings represent the range of loadings across items within each construct.*

AI (AAI), Evaluating AI Application (EAIA), and AI Ethics (AIE) were above the neutral point (3 on the Likert scale), ranging from 3.45 to 4.01, indicating moderate levels of AI literacy. The constructs showed moderate correlations with each other. Among demographic elements, age exhibited stronger correlations with KUAI, AAI, and EAIA.

## Measurement Model

Preliminary tests were conducted to validate the items in the four main constructs (KUAI, AAI, EAIA, and AIE) through confirmatory factor analysis (CFA). The analysis ensured that each item loaded significantly onto its respective latent construct, confirming the factorial validity of the measurement model. Items with factor loadings exceeding 0.7 were retained, as suggested by Sanchez (2013), indicating that they effectively represented the underlying dimensions of AI literacy among teachers.

Reliability analysis using Cronbach's α coefficient was performed to assess the internal consistency of each construct. According to Nunnally (1978), a Cronbach's α value greater than 0.7 indicates high reliability of measurement. In this study, all constructs demonstrated high reliability ($\alpha > 0.7$), indicating that the questionnaire items consistently measured their intended constructs.

## Structural Model

The structural model was developed to examine the relationships between demographic variables (sex, location, educational background, age) and the latent constructs of AI literacy (KUAI, AAI, EAIA, AIE). The hypothesized model included paths indicating the direct effects of demographic variables on AI literacy constructs and the interrelationships among the constructs themselves. Path coefficients were estimated to quantify the strength and direction of these relationships. The goodness-of-fit of the structural model was assessed using several fit indices: chi-square test, comparative fit index (CFI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR). A good fit of the model was indicated by a non-significant chi-square value, CFI > 0.9, RMSEA < 0.08, and SRMR < 0.08.

Based on the SEM results, non-significant paths between variables were removed after revising the hypothesized research model. All statistically significant path coefficients in the model were retained. Figure 2 illustrates the majority of hypotheses were accepted, except for a few non-significant paths (e.g., H3b). Additionally, Table 5 presents the standardized path coefficients and direct effects in the hypothesized model.

**Table 4:** Results of the Fitness in the Hypothesis Model

| | *p-value* | *CFI* | *RMSEA* | *SRMR* |
|---|---|---|---|---|
| Structural Model | 0.000 | 0.911 | 0.079 | 0.060 |
| Fit Criteria | <0.001 | >0.9 | <0.08 | <0.08 |

**Table 5:** Path coefficient estimates in the hypothesized model.

| *Hypothesis* | *Path Coefficient (β)* | *Direct Effects* | *SE* |
|---|---|---|---|
| H2a: AAI→KUAI | 0.88 *** | 0.88 | 0.020 |
| H2b: AAI→EAIA | 0.11 *** | 0.11 | 0.021 |
| H2c: AAI→AIE | 0.53 *** | 0.53 | 0.028 |

Note: *** p < 0.001. KUAI, Knowing and Understanding AI; AAI, Applying AI; EAIA, Evaluating AI Application; AIE, AI Ethics.

## Hypotheses Testing Results

### *Hypothesis1. A positive correlation exists between Knowing and Understanding AI and Evaluating AI Application. (Supported):*

This first hypothesis posited that teachers' knowledge and understanding of AI (KUAI) would positively predict their ability to evaluate AI applications (EAIA). The results provided strong support for this hypothesis ($\beta = 0.82$, $p < 0.001$), indicating that teachers who possess a deeper understanding of AI concepts and functionalities are more likely to effectively assess its applications in educational settings. This finding underscores the importance of comprehensive AI literacy among educators, as it enhances their capacity to critically evaluate and leverage AI tools for instructional purposes.

### *Hypothesis2. Applying AI has a positive effect on Knowing and Understanding AI, Evaluating AI Application, and AI Ethics. (Supported):*

The second hypothesis proposed that applying AI (AAI) in educational contexts would positively influence three aspects of AI literacy among teachers: Knowing and Understanding AI (KUAI), Evaluating AI Application (EAIA), and AI Ethics (AIE). The results strongly supported this hypothesis, revealing significant positive effects of applying AI on KUAI ($\beta = 0.88$, $p < 0.001$), EAIA ($\beta = 0.11$, $p < 0.001$), and AIE ($\beta = 0.53$, $p < 0.001$). This suggests that hands-on experience with AI technologies enhances teachers' understanding of AI concepts, improves their ability to evaluate AI applications critically, and sensitizes them to ethical considerations related to AI use in education. Practical exposure to AI thus plays a pivotal role in fostering comprehensive AI literacy among educators.

### *Hypothesis3. AI Ethics has a positive effect on Knowing and Understanding AI and Evaluating AI Application. (Partially Supported):*

The third hypothesis examined the influence of AI ethics (AIE) on teachers' Knowing and Understanding AI (KUAI) and Evaluating AI Application (EAIA). The results partially supported this hypothesis, indicating a significant positive effect of AI ethics on KUAI ($\beta = 0.17$, $p < 0.001$) but no significant effect on EAIA ($\beta = 0.05$, $p > 0.05$). This suggests that while ethical considerations are important in shaping educators' understanding of AI principles

and functionalities, their impact on the evaluation of AI applications appears to be less pronounced. Educators may prioritize ethical awareness and responsible AI use in their teaching practices, contributing to a broader understanding of AI's societal implications, but this awareness may not consistently translate into critical evaluation skills for AI applications in educational contexts.

## Conclusions and Implications

This study underscores the importance of AI literacy among teachers across different educational stages, highlighting its acceptance and relevance. However, the current educational programs fall short in providing comprehensive and high-quality AI education. There is an urgent need for a substantial overhaul of teacher education programs to foster the development of AI literacy among educators. The study's model demonstrates significant correlations among various dimensions of AI literacy, suggesting a transformative impact on teachers' cognition, teaching methodologies, and recommendations regarding AI integration. Governmental intervention is crucial to cultivate AI literacy among teachers, necessitating policies and dedicated institutions for teacher education. Proposed measures include online platforms for flexible learning, weekly assignments for practical application, and personalized study schedules. Incorporating new AI technologies into training and teaching processes, along with robust assessment mechanisms, is essential to ensure teachers grasp the structural principles and operational aspects of AI.

The findings emphasize the necessity for teacher training programs to evolve in supporting real-world competencies in digital societies. This necessitates continuous learning across all levels, encompassing technical competencies and innovative AI practices. Recommendations underscore the importance of considering demographic variables such as sex, location, educational background, age, and job title in designing effective training programs. Motivation and attitudes toward AI emerge as critical factors influencing AI literacy and should be prioritized alongside conceptual and instructional content considerations.

As educational levels rise, AI literacy levels tend to decrease, underscoring the pivotal role of elementary school teachers in developing foundational AI literacy among vulnerable student populations. Policy frameworks integrating AI applications inclusively are essential for advancing teacher AI education. Attention to AI ethics during teacher induction is crucial to prevent uni-dimensional educational models centered solely on technological advancements. Moving forward, personalized teacher education programs grounded in data models could facilitate the development of AI literacy among educators. Enhancing teachers' AI literacy not only supports their professional growth but also enables them to adapt effectively to the evolving demands of the digital era, fostering new professional identities and facilitating role transformations.

## Recommendation

The findings underscore the pivotal role of government intervention in fostering AI literacy among teachers in Punjab. Government-led initiatives, such as funding AI-specific training programs and establishing AI literacy centers, can address the identified gaps in teacher preparedness. Policies promoting equitable access to AI education resources, especially in rural and suburban areas, are crucial. Moreover, integrating AI ethics and application-oriented curricula into teacher training programs can enhance the quality and scope of AI literacy. By facilitating partnerships between academic institutions and industry stakeholders, the government can ensure that teachers are equipped with practical AI competencies, ultimately benefiting the broader educational landscape.

## Limitations and Future Research

This study acknowledges two primary limitations. Firstly, the survey sample was non-randomly selected, predominantly comprising teachers from rural areas in Punjab, India. Consequently, the findings cannot be generalized to all teacher populations across Punjab, India. Future research should address this limitation by employing probabilistic or purposeful sampling methods to capture diverse perspectives across different educational stages and geographic regions.

Secondly, the study relied solely on one-time quantitative data collection, limiting the depth of understanding that could be achieved. Future research endeavours should incorporate complementary qualitative data to enrich the interpretation of quantitative findings. Longitudinal studies are recommended to assess sustainable developments in teachers' AI literacy and draw more robust conclusions.

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