A TPACK-Assisted Descriptive Analysis of the Sri Lankan ICT Teachers' Readiness to Teach AI in Schools

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***Abstract*—The integration of Artificial Intelligence (AI) into school curricula is a growing global initiative. While significant research addresses AI content and pedagogy, a pervasive challenge is ensuring the teaching workforce is adequately prepared to implement these curricula effectively. This paper addresses this crucial gap within the Sri Lankan context, investigating two primary issues: 1) the knowledge gaps—technical, pedagogical, and content—between curriculum stipulations and in-service teacher competencies, and 2) how teachers' background variables contribute to these knowledge deficits. Employing a descriptive analysis of a secondary dataset mapped to the Technological, Pedagogical, and Content Knowledge (TPACK) framework, this study reveals three key findings. Firstly, Sri Lankan ICT teachers exhibit significant deficiencies across all three knowledge domains. Secondly, the deficit in content knowledge is substantially more pronounced compared to the other two areas. Finally, results indicate that female teachers possess considerably lower knowledge levels than their male counterparts, suggesting a critical need for more personalised attention within future teacher development programs. These findings offer crucial and actionable insights for policymakers and teacher educators responsible for designing professional development initiatives. The study particularly recommends adopting the systems thinking approach for the teacher professional development initiatives.**

***Keywords*—AI4K12, artificial intelligence, knowledge gaps, teacher professional development, Technological, Pedagogical, and Content Knowledge (TPACK), Information and Communication Technology (ICT) teachers**

I. Introduction

Artificial Intelligence (AI) has achieved widespread ubiquity, with AI-driven applications emerging at an unprecedented pace [1]. This rapid proliferation introduces a multitude of challenges for both individuals and organisational structures. Recognising this, numerous countries have already initiated efforts to equip future generations with AI competencies, ensuring their preparedness to confront the extensive societal and corporate shifts that AI technologies are poised to bring [2–4]. Among these initiatives, the integration of Artificial Intelligence into school curricula has recently attracted considerable focus, prompting a concerted effort from various nations, non-governmental organisations, and academic researchers to develop comprehensive curriculum content spanning from kindergarten to high school [5–8].

While there is a significant focus on curriculum design, the educators responsible for teaching the material are often overlooked [6, 9, 10]. For this reason, teacher professional development—which builds a teacher's skills, knowledge, and expertise—is a critical component of the AI4K12 initiative [10, 11]. As students become increasingly comfortable with technology, it's essential that their teachers are well-prepared to manage a modern classroom. Since artificial intelligence is a new topic for most educators, its introduction has already raised concerns among them. Existing research confirms this, revealing significant gaps in teachers' confidence and overall readiness to teach AI effectively [12, 13]. As pointed out in [11], many teachers have reported a lack of confidence in their understanding because they often lack access to relevant technological pedagogical content knowledge. Moreover, according to [2] and [13], the emergence of AI education as a subject places new demands on teachers, researchers, and policymakers to ensure its effective implementation in schools.

The literature indicates a need to explore two critical questions in order to design effective teacher professional development programs for AI education.

1) What knowledge gaps—technical, pedagogical, and content—exist between what's stipulated in curricula and the in-service teachers [6].
2) How the differences in the teachers' backgrounds contribute to their knowledge gaps [14].

The first question helps evaluate how well the existing teachers can deliver the expected content. Many of the existing studies on teacher development use the Technological, Pedagogical and Content Knowledge (TPACK) framework [15] to identify potential lapses in their knowledge [16, 17]. According to [14], understanding teachers' backgrounds, which include their educational degrees, subject area expertise, teaching experience, and professional teacher training, is crucial because that information can provide insights into how their experiences and training have shaped their TPACK readiness.

Although numerous studies have explored teachers' readiness for technology integration through the TPACK framework [18], only a limited subset has specifically examined AI education within this framework [19]. Most prior studies employing the TPACK framework have primarily examined general ICT or computer science integration, where technology is treated as a pedagogical tool to facilitate learning. In contrast, AI education positions technology simultaneously as content, process, and societal concern, introducing distinct cognitive and ethical dimensions. Moreover, the majority of existing research has been conducted in high-income or early-adopting countries [6], with limited empirical attention to developing nations, where infrastructural constraints, training opportunities, and curricular exposure differ significantly. Consequently, there remains a conceptual and empirical gap in understanding how TPACK manifests in teachers preparing to teach AI in such contexts.

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This paper addresses these two questions within the Sri Lankan context. Since 2021, Sri Lanka has been implementing educational reforms to integrate AI into the secondary school ICT curriculum. While substantial changes are planned for the future, several essential AI topics have already been added to the existing curriculum as an interim measure. These include a general introduction to AI, an overview of key technologies, and a discussion of its social and ethical implications. Teacher training is primarily led by the Ministry of Education and the National Institute of Education, with support from university academics and private sector organisations. However, to our knowledge, no previous study has empirically examined Sri Lankan teachers' readiness to teach AI through a structured theoretical lens such as TPACK.

While this study is grounded in the Sri Lankan context, its findings hold broader relevance. By unveiling the existing knowledge gaps among the teachers and analysing how the differences in the teachers' backgrounds contribute to those knowledge gaps, it contributes to the global conversation on how nations at different stages of sociotechnological maturity can prepare their teaching workforces for AI education. The study presented in this paper is primarily descriptive and makes use of an existing dataset collected from an island-wide survey involving more than 1200 ICT teachers. Even though the dataset was not collected using a dedicated survey instrument, all efforts were made to align the data as closely as possible with the TPACK framework.

This study contributes to the existing body of research in several ways. Theoretically, it extends the TPACK framework into the emerging domain of AI education, thus testing its applicability beyond traditional ICT integration contexts. Methodologically, it demonstrates how the existing secondary data can be realigned with TPACK constructs to extract meaningful readiness insights, offering a practical approach for researchers having limited data collection resources. Practically, it provides policymakers and teacher educators with evidence-based insights into which components of teachers' TPACK—technological, pedagogical, or content knowledge—require the most attention as AI becomes part of the school curriculum.

This paper is organised into five sections. Section II provides a review of the relevant literature. Section III details the research methodology. Section IV presents the analysis and discussion of the findings, including recommendations. Section V concludes the paper by summarising the key findings, acknowledging the study's limitations, and proposing avenues for future research.

II. Literature Review

Many countries, organisations, and researchers have proposed curricula for teaching AI in schools [5]. One of the most established and widely cited of these is the AI4K12 project, a joint initiative in the United States from the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers' Association (CSTA). The AI4K12 curriculum is organised around 'five big ideas': Perception, Representation and Reasoning, Learning, Natural Interaction, and Societal Impact. Furthermore, the project offers detailed guidelines that tailor the content for different age groups [20]. Referring to the five big ideas of the AI4K12 project, Touretzky *et al*. offer a similar analysis, categorising a set of existing tools and content [21]. Their work also showcases some key efforts to develop new curriculum resources. In another notable work, UNESCO has comprehensively researched the existing K12-level AI teaching initiatives in different countries and recommends actions on development, management, implementation of curricula and training teachers [5]. Following a comprehensive review of existing curricula, reference [7] has proposed a new curriculum for high school students in the European Union. Designed to span two academic years, it consists of eight key topics: Perception, Actuation, Representation, Reasoning, Learning, Artificial Collective Intelligence, Motivation, and a final topic on the Sustainability, Ethics, and Legal Aspects of AI. Notably, the entire curriculum is based on the concept of an intelligent agent.

Mazzucato and Gaudiello have compiled a comprehensive report for the Edu4AI project, which focuses on using AI to build 21st-century skills in secondary schools [22]. This report catalogues a wide array of resources, tools, and publications, sorted into teacher-oriented and student-oriented sections. The materials are designed for both learning the fundamentals of AI and using AI. However, the report functions as a broad index of resources rather than a curated guide that directs users to specific content appropriate to their profile. In a related study, Rizvi *et al.* review academic literature published between 2019 and 2022 [23]. They analyse these publications based on several factors, including their learner context, pedagogical settings, learning outcomes, and the key AI concepts covered. One of their key observations is a clear bias in the research: most studies focus on introducing AI models while neglecting both the deeper technical (engine-level) details and the crucial social and ethical implications of AI.

The TPACK framework is a popular tool for researchers who want to assess the different aspects of a teacher's knowledge and how those aspects interact [24]. At its core, TPACK outlines three fundamental knowledge areas: Technical (TK), Pedagogical (PK), and Content (CK). The framework's strength lies in how it combines these areas to define their intersections, including Technical-Pedagogical Knowledge (TPK), Pedagogical-Content Knowledge (PCK), Technical-Content Knowledge (TCK), and the holistic Technical, Pedagogical, and Content Knowledge (TPCK) [15]. While the TPACK framework was originally created to assess how teachers use digital technologies for instruction, it has since been widely used by other studies to better understand teacher competencies and help design professional development programs [14].

The recent research on TPACK has identified the increasing adoption of AI technology in teaching and learning [17]. Consequently, the Intelligent TPACK (AI-TPACK) framework has been developed to facilitate the integration of AI-based applications into educators' teaching practices [25]. The AI-TPACK framework consists of five fundamental components, namely AI Technological Knowledge (AI-TK), AI-Technological Pedagogical Content Knowledge (AI-TCK), AI-Technological Pedagogical Knowledge (AI-TPK), and Ethics [26]. Based on the AI-TPACK framework, Çelik has developed a scale to measure teachers' knowledge for instructional AI use, while also incorporating the ethical dimensions of AI integration [17]. Furthermore, their model has examined the interplay between TPACK components and ethical awareness. The findings indicated that teachers with greater knowledge of AI-based tools tend to better understand the pedagogical contributions of AI. Additionally, enhanced technological knowledge (TK) was found to improve teachers' ability to critically assess AI-driven decisions. However, much of the existing research on AI-TPACK continues to conceptualise AI primarily as a pedagogical tool to support teaching and learning, without sufficiently addressing the broader epistemic and ethical requirements of AI as a subject of education.

In their research on teacher AI literacy, Ng *et al.* have sought to establish a sound theoretical foundation for how to define, teach, and evaluate the subject [27]. Based on a literature review, they have identified four key aspects that foster this literacy: knowing and understanding AI, using and applying AI, evaluating and creating AI, and understanding AI ethics. In the paper, they have aligned the concept of AI literacy with both Bloom's Taxonomy and the TPACK framework. Notably, their application of TPACK is limited to its three core knowledge areas: Technical (TK), Pedagogical (PK), and Content Knowledge (CK). They have classified items for each as follows:

- **Technical Knowledge (TK)**—hardware and software, AI-related agents, unplugged artefacts, and gamified elements
- **Pedagogical Knowledge (PK)**—discovery and inquiry-based learning, collaborative learning, constructionism, project or problem-based learning, unplugged methods like storytelling, and hands-on or playful learning.
- **Content Knowledge (CK)**—AI awareness, AI ethics, the AI syllabus by Russell and Norvig [28], and the 'Five Big Ideas of AI' [20].

In a comparative study, Kim *et al.* have evaluated teacher professional development programs for AI education across five nations: the United States, China, India, Australia, and South Korea [6]. Their review encompasses a wide range of national initiatives, including the AI4K12 framework in the US [20] China's "New Generation of Artificial Intelligence Development Plan [29]" the elective AI curriculum from India's Central Board of Secondary Education [30], and Australia's CSER Digital Technologies MOOC Program [31].

The study provides a particularly detailed analysis of South Korea's multifaceted approach, examining its block-based programming tools used to enhance computational thinking [32], the AI Learning Framework by the Korea Foundation for the Advancement of Science and

Creativity, the Guideline for Software Education by the Korea Information Science Education Federation [33], online AI lectures from the Educational Broadcasting System (EBS), and an AI workbook by the Association of Teachers for Computing (ATC).

Building on their analysis of these curricula, Kim *et al.* propose a set of teacher competencies for K-12 AI education. These competencies, conceptualised within the TPACK framework, are detailed in Table 1.

Table 1. Required teacher competency for AI according to each TPACK element

TPACK	Required competency of teachers for K-12 AI education
PK	Facilitate project-based learning Organise essential concepts and principles into play and games
PCK	Classroom management and problem-solving based activity construction on AI technologies and AI social issue awareness
CK	Fundamentals of AI (problem-solving, inference, learning, recognition) Computer Science (programming, algorithms) Applied Mathematics (probability, statistics, calculus) AI ethics
TK	Using ICT tools and educational software Construct programming environment
TCK	Using web or API-based online education platforms for AI project education
TPK	Provide feedback and encourage peer-reviewing of AI project outcomes shared in open online education platforms

III. Materials and Methods

This study adopts a secondary research design [34], utilising a pre-existing dataset collected by Rajapakse *et al.* [12] to investigate the readiness of Sri Lankan ICT teachers for AI education, as conceptualised by self-efficacy theory. The decision to leverage secondary data was threefold: 1) to establish foundational insights that can inform subsequent primary research, 2) to optimise research efficiency and expedite outcomes, and 3) to mitigate respondent fatigue by avoiding repeated data collection. While this methodology is a widely accepted practice, the authors fully acknowledge the limitations associated with the secondary use of data [35] for this investigation.

A. Sample, Data Collection and Ethical Practice

The data used in this study were collected through a survey conducted between June and July 2023, employing a snowball sampling method. The questionnaire was administered in both native languages of the country: Sinhala and Tamil. Prior to data collection, all respondents were clearly informed of the study's objectives. Furthermore, the questionnaire included a statement assuring participants of the privacy and confidentiality of their individual responses. A total of 1236 responses were received from ICT teachers across the island. After removing the incomplete responses, a total of 892 responses were used for the analysis. This sample represents approximately 15% of the estimated 6,500 ICT teachers in the country. The key characteristics of the respondents were as follows [12].

- 70% of the respondents were females
- 60% of the respondents belonged to the age category of 31-40 years
- Only about 6% of the respondents were above 50 years old
- 44% had a bachelor's degree, and 22% had postgraduate qualifications
- Only 42% had a science (STEM) education background[1]
- Only 20% had studied mathematics for their school-leaving examination
- 50% of the respondents had a service of 10-20 years

While snowball sampling presents a potential for bias, this risk was mitigated by having domain experts at the National Institute of Education verify key sample characteristics, such as the male-female ratio and the ethnicity ratio.

[1] This was determined by the academic stream of their school-leaving exam

Table 2. The original instrument used to get the secondary dataset adopted for this study

ID	Efficacy Question
EF01	Teaching Artificial Intelligence (AI) to school children could be challenging, but I am confident that I can overcome these challenges with hard work and dedication
EF02	I am eager to get an opportunity to teach AI
EF03	When teaching or learning subjects related to new technology, I feel energetic and motivated
MS01	I have studied the subject 'Artificial Intelligence' at the University/National College of Education (NCoE)
MS02	I am confident in my ability to identify common applications of AI and the techniques used to implement them
MS03	I have applied AI techniques to develop solutions for real-world problems
MS04	Learning and teaching new technologies have always presented challenges for me, but I have consistently been able to overcome them
MS05	I actively stay informed about emerging AI technologies by following their development and learning about them. This allows me to maintain a strong understanding of current AI advancements
MS06	I frequently help friends, students, and colleagues understand AI technologies by answering their questions effectively
MS07	I actively seek out new teaching/learning tools, methods, and evaluation strategies related to AI, and integrate them into my teaching or learning practices
MS08	While teaching Information Technology (IT) to young children who are comfortable with technology, I rarely encounter situations where my own knowledge is challenged, which can sometimes make me feel uneasy
MS09	The students who take my Information Technology class typically achieve high scores on exams
MS10	I make a consistent effort to attend seminars and workshops on AI offered by various organisations and universities whenever possible
MS11	In my teaching, I frequently encourage and guide students to explore innovative projects that utilise modern information technologies, including AI
MS12	I actively participate in media programs and workshops as a resource person to increase public awareness and understanding of modern information technologies
MS13	I have cultivated a strong network of contacts within software development companies and other businesses that are actively using or exploring AI
VC01	I actively follow and am inspired by excellent teachers who excel at explaining complex subjects like AI in a clear and engaging manner, tailored to the age and understanding level of their students. This approach helps me refine my own teaching style
VC02	My fellow Information and Communication Technology (ICT) teachers, with whom I regularly interact, share a strong interest in exploring and teaching AI
VC03	I have access to a mentor with expertise in artificial intelligence (AI) who can provide guidance and support in resolving any challenges I encounter while teaching or learning AI
VP01	Students and colleagues frequently commend me for my ability to effectively teach complex Information and Communication Technology (ICT) subjects
VP02	During my studies at the University/National College of Education, my peers and instructors recognised me as having a strong grasp of ICT and/or AI
SC01	I possess the necessary intellectual stamina and dedication to continuously learn and update my knowledge of AI, allowing me to effectively teach this subject.
SC02	Even with the extra preparation involved, teaching a demanding subject like AI doesn't necessarily stress or discourage me
IM01	I aspire to become a highly regarded educator, recognised for my expertise in AI and its potential impact on the future.
IM02	Witnessing my students achieve success in the Information Technology (IT) sector, both locally and internationally, is a significant source of satisfaction for me as a teacher.
EX01	Limited resources like computers, internet access, and labs at my school don't significantly hinder my ability to effectively teach AI
EX02	I am confident that the school administration would be supportive in addressing any challenges that may arise while teaching AI
EX03	I believe my students' existing knowledge, computational skills, critical thinking abilities, and everyday experiences provide a strong foundation for understanding AI
EX04	I am confident the government will offer us comprehensive and adequate training opportunities for teaching AI

While the survey instrument from Rajapakse *et al*. was originally designed to evaluate teacher readiness through the lens of Bandura's self-efficacy theory [36], its application for assessing the core components of TPACK is theoretically well-founded. The literature establishes a strong, reciprocal relationship between a teacher's knowledge and their sense of efficacy [37]. This connection is grounded in Bandura's Social Cognitive Theory [38], which posits that learning (knowledge acquisition) is essential for developing the confidence required to engage in effective action [39]. This principle has been explicitly extended to the TPACK framework, leading to the concept of "TPACK self-efficacy"—defined as a teacher's confidence in their ability to effectively integrate technology, pedagogy, and content knowledge [40]. Consequently, a teacher's self-efficacy in these specific domains can serve as a valid proxy for their underlying knowledge. Assessing their confidence in using technology (TK), employing pedagogical strategies (PK), and understanding AI concepts (CK) provides a robust measure of their readiness. This alignment can be further strengthened by research that maps Bandura's original sources of self-efficacy, such as mastery experiences, directly onto the elements of the TPACK framework.

The instrument consisted of 29 items allocated across several constructs: three questions assessed general self-efficacy, thirteen assessed mastery experience, three assessed vicarious experience, two assessed verbal persuasion, two assessed physiological and emotional states, and two assessed imaginal experiences. An additional four items were included to evaluate the influence of external factors. Responses for all items were captured on a four-point Likert scale: (a) Totally disagree, (b) Agree to some extent, (c) Mostly agree, and (d) Fully agree. The complete set of self-efficacy questions is presented in Table 2.

B. *Instrument for Evaluating the Knowledge Gaps*

To map the items from the Rajapakse *et al*. questionnaire to the TPACK framework, a comparative analysis was conducted against the validated TPACK instrument developed by Schmidt *et al*. [41]. This process identified the most relevant items for our analysis, which were intentionally limited to the core TPACK domains of Technological (TK), Pedagogical (PK), and Content Knowledge (CK). The rationale for this focus is that in a nascent field like AI education, establishing a foundational baseline of these core competencies is a necessary precursor to evaluating the more complex, integrated knowledge forms. Specifically, it is essential to first determine whether teachers possess the fundamental building blocks: an understanding of AI concepts (CK), the ability to use AI tools (TK), and a grasp of general teaching strategies (PK). This approach allows for the creation of a clear, foundational map of teacher readiness before exploring the more nuanced intersections of the framework.

To measure Technological Knowledge (TK), five items were selected from Table 2. The selection was guided by the seven TK items in the instrument developed by Schmidt *et al*. (Table 3), which defines TK as knowledge of technologies ranging from low-tech to digital. By comparing the items from both questionnaires, the five most appropriate items from Table 2 were selected to represent the TK construct. These selected items are presented in Table 4.

Table 3. The seven TK items in the instrument developed by Schmidt *et al*.

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA					
1. I know how to solve my technical problems	SD	D	N	A	SA
2. I can learn technology easily	SD	D	N	A	SA
3. I keep up with important new technologies	SD	D	N	A	SA
4. I frequently play around with the technology	SD	D	N	A	SA
5. I know about a lot of different technologies	SD	D	N	A	SA
6. I have the technical skills I need to use technology	SD	D	N	A	SA
7. I have had sufficient opportunities to work with different technologies	SD	D	N	A	SA

Table 4. The items selected from Table 2 to evaluate the Technological Knowledge

Item Selected	Alignment with Table 3	Author's Reasoning
EF03	I can learn technology easily	Positive emotional state Ease towards learning technology
MS04	I know how to solve my own technical problems I can learn technology easily	Ability to learn and master new technologies
MS05	I keep up with important new technologies	Staying current with new technology
MS08	I have the technical skills I need to use technology	Self-assessment of the teacher's own broad technical knowledge in IT
VP02	I know about a lot of different technologies	Reflects the general technical proficiency and knowledge in ICT

The instrument developed by Schmidt *et al*. measures Content Knowledge (CK) using a set of three core items. This set is replicated across four distinct academic disciplines: Mathematics, Social Studies, Science, and Literacy. As an example, the three items specific to Mathematics are presented in Table 5. Five items from Table 2 were selected under the guidance of Table 5 to represent the Content Knowledge, which is defined as the knowledge about actual subject matter that is to be learned or taught. The details of the selected items are presented in Table 6.

The core items that measure the Pedagogical Knowledge (PK) according to Schmidt *et al*.'s survey instrument are listed in Table 7. Aligned with those items, another three items were selected from Table 2 to represent the Pedagogical Knowledge, which is defined as the methods and processes of teaching and includes knowledge in classroom management, assessment, lesson plan development, and student learning. The details of the selected items are presented in Table 8.

Table 5. The three CK items in the instrument developed by Schmidt *et al.*

Mathematics					
8. I have sufficient knowledge about mathematics	SD	D	N	A	SA
9. I can use a mathematical way of thinking	SD	D	N	A	SA
10. I have various ways and strategies of developing my understanding of mathematics	SD	D	N	A	SA

Table 6. The items selected from Table 2 to evaluate the Content Knowledge

Item Selected	Alignment with Table 5	Author's Reasoning
MS01	I have sufficient knowledge about [the subject]	Indicates a formal foundational knowledge
MS02		A direct assessment of the teacher's knowledge of both the practical applications and the underlying technical methods of AI
MS06		Possesses the mastery to teach others
MS03	I can use the [subject-specific] way of thinking	Shows the ability to move beyond theory and actively use AI methodologies to create a tangible solution
MS10	I have various ways and strategies of developing my understanding of [the subject]	Confirms that the teacher has a clear, active strategy for deepening his/her own understanding of the subject matter

The responses to the selected survey items were used to analyse the Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) components of the TPACK framework. This analysis was conducted with reference to the teacher competencies proposed by Kim *et al*. (Table 1). To further deepen the analysis of Content Knowledge, the study also utilised an additional question from the Rajapakse *et al*. questionnaire. This question assessed teachers' self-reported competency in twelve key AI topics: State Space Search, Genetic Algorithms, Knowledge Representation and Reasoning, Intelligent Agents, Machine Learning, Artificial Neural Networks, Swarm Intelligence, Multi-Agent Systems, Fuzzy Logic Systems, Natural Language Processing, Computer Vision, and Ethics and Social Responsibilities.

Table 7. The seven CK items in the instrument developed by Schmidt *et al*

Strongly Disagree = SD Disagree = D Neither Agree/Disagree = N Agree = A Strongly Agree = SA					
20.I know how to assess student performance in a classroom	SD	D	N	A	SA
21.I can adapt my teaching based on what students currently understand or do not understand	SD	D	N	A	SA
22.I can adapt my teaching style to different learners	SD	D	N	A	SA
23.I can assess student learning in multiple ways	SD	D	N	A	SA
24.I can use a wide range of teaching approaches in a classroom setting	SD	D	N	A	SA
25.I am familiar with common student understandings and misconceptions	SD	D	N	A	SA
26.I know how to organise and maintain classroom management	SD	D	N	A	SA

Table 8. The items selected from Table 2 to evaluate the Pedagogical Knowledge

Item Selected	Alignment with Table 7	Author's Reasoning
VC01	I can adapt my teaching style to different learners I can adapt my teaching based on what students currently understand	Reflects the teacher's strong desire to tailor complex subjects (like AI) to the specific understanding level of the students
MS07	I can use a wide range of teaching approaches in a classroom setting	Demonstrate the teacher's commitment to finding and using a variety of teaching approaches and tools
MS11		Demonstrate the use of project-based learning

C. Construct Validity

To validate the use of the self-efficacy questionnaire items for measuring teachers' technological, content, and pedagogical knowledge (TK, CK, PK), a split-sample factor analysis was conducted. A randomly selected 30% of the sample (N = 263) was used for exploratory factor analysis (EFA) with maximum likelihood estimation and varimax rotation. Results supported a three-factor solution consistent with TK, CK, and PK, with most items loading strongly on their respective factors and minimal cross-loadings. Model fit indices indicated excellent fit (RMSR = 0.03, TLI = 0.999, RMSEA = 0.003). The remaining 70% of the sample (N = 630) was used for confirmatory factor analysis (CFA), which largely confirmed the three-factor structure. All items loaded significantly on their intended factors (standardised loadings 0.426–0.795), and fit indices were acceptable (SRMR = 0.061, CFI = 0.870, TLI = 0.837), supporting construct validity. Cronbach's alpha values indicated acceptable to good internal consistency for each factor: TK = 0.69, CK = 0.76, and PK = 0.62, with item-total correlations demonstrating that all items contributed positively to their respective scales. Together, these analyses provide robust evidence that the self-efficacy questionnaire reliably and validly measures teachers' basic TPACK components.

D. Analysis of Teacher Backgrounds

To address the second objective of this study, an analysis was conducted to determine the impact of teachers' background characteristics on their Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Guided by the framework from Yue *et al*. [14], a teacher's background was defined by several variables: age, ethnicity, educational qualifications, teaching experience, and academic major. The dataset used for this study contained all the necessary data for this analysis.

Educational background was captured through a multiple-response question, with options including First Degree, National Diploma in Education, Postgraduate Qualification, Trained Teacher, and other relevant professional qualifications (e.g., CCNA, ACS, BCS). Teaching experience was categorised into four brackets: less than 5 years, 5 to 10 years, 10 to 20 years, and more than 20 years. Finally, the academic major was based on the teacher's school-leaving examination stream, such as Biological Science, Mathematics, Commerce, Arts, or Technology.

E. Data Analysis

This study employs a quantitative, descriptive approach to data analysis. As detailed previously, thirteen survey items were selected, corresponding to the core TPACK domains: five for Technological Knowledge (TK), five for Content Knowledge (CK), and three for Pedagogical Knowledge (PK). To identify knowledge gaps, we analysed the frequency distribution of responses for each item across the four-point agreement scale. These response patterns were visualised using bar charts to provide a clear descriptive overview.

Furthermore, a descriptive analysis was conducted to explore the influence of teacher demographics on these knowledge components. For this, we calculated the proportion of respondents who selected the two lowest agreement options for each demographic category (e.g., age group). These proportions were then visualised using bar charts to facilitate a comparative analysis and draw further insights.

IV. Results and Discussion

A. Gaps in Teachers' Knowledge—TK, CK, and PK

As outlined in Table 1, the Content Knowledge (CK) competencies for AI teachers proposed by Kim *et al*. [6] encompass both the fundamentals of AI (e.g., problem-solving, inference, learning) and AI ethics. This includes specific topics such as heuristic search algorithms, knowledge representation, machine learning, deep learning, computer vision, natural language processing, and the ethical implications of AI. The adopted questionnaire included a dedicated item to assess respondents' self-reported knowledge of key AI topics. These topics, which were aligned with those in the study by Kim *et al*., were rated on a five-point scale. Fig. 1 summarises the responses, showing the number of responses for each scale point.

As illustrated in Fig. 1, a substantial portion of teachers reported having no knowledge or merely a superficial awareness of the listed AI techniques. This knowledge gap is evident across a range of topics, from specialised areas like swarm intelligence and genetic algorithms to more widely known concepts such as machine learning and neural networks, where the majority of respondents still indicated minimal understanding. Overall, these results point to an alarmingly low level of AI-related Content Knowledge (CK). This deficiency becomes particularly stark when measured against the competency standards established by Kim et al. and the broader literature, highlighting a critical lapse in teacher readiness for AI education.

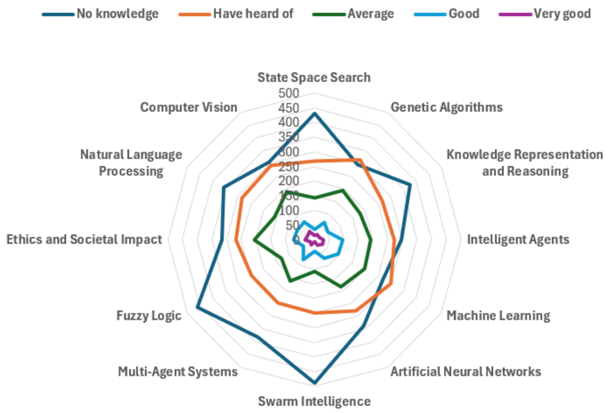

Fig. 1. The respondents' self-evaluated knowledge on key AI topics.

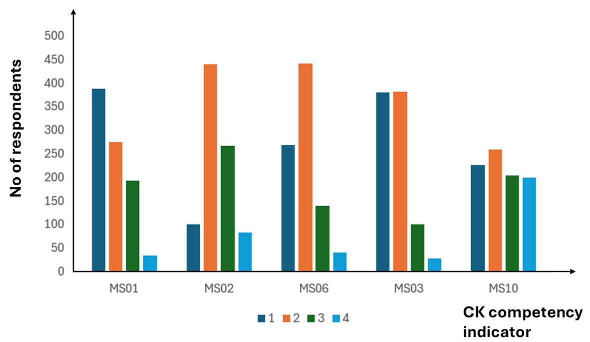

Fig. 2. The response pattern for each Content Knowledge (CK) indicator.

Analysis of the CK items in Table 6 highlights specific areas of weakness in teachers' AI knowledge (See Fig. 2). For items MS01, MS02, and MS06, which address fundamental AI concepts, 68–75% of respondents selected the lowest two options (1 = totally disagree, 2 = agree to some extent), reflecting a low self-perception of competence. Item MS03, concerning the application of theoretical AI methodologies to practical problems, showed a similar trend, indicating limited confidence in translating knowledge into tangible solutions. This finding also has direct implications for teachers' capacity to facilitate project-based learning, a critical pedagogical skill [42]. In contrast, responses to item MS10, related to participation in seminars and workshops, were more evenly distributed, with a substantial subset of teachers reporting moderate to high engagement. Nevertheless, the fact that a slight majority still report low participation underscores a persistent gap in opportunities for professional development in AI content knowledge.

Fig. 3 illustrates the responses to the Technological Knowledge (TK) indicators, which are detailed in Table 4. While the responses to items EF03 and MS04 suggest a higher level of perceived technical competency based on the percentage of respondents selecting the lowest two options (options 1 and 2), a significant challenge is revealed in the responses to item MS05. The large majority of teachers selected low-agreement options for this item, indicating a disinclination to actively keep up with advancements in AI technology. As AI is also a critical teaching-support tool, this represents a substantial issue in the teachers' overall technological knowledge.

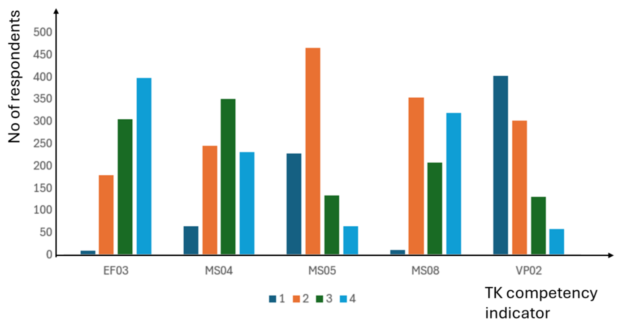

Fig. 3. The response pattern for each Technological Knowledge (TK) indicator.

The response pattern for item MS08 also reveals an interesting finding. Although 60-65% of teachers selected the highest two options (3 and 4), indicating comfort in teaching a technology-related subject to tech-savvy children, a notable proportion still reported occasional difficulties (options 1 and 2). This suggests a challenge not only in technology pedagogy but also in classroom management. Furthermore, while it is not a definitive measure of current technical proficiency, the low-agreement responses to item VP02 indicate that most respondents have not been recognised for their tech-savviness in the past.

Collectively, these findings suggest that the teachers' technological knowledge is currently insufficient to meet the challenges of teaching an advanced technological subject like AI. However, since the extended AI-TPACK framework [17] conceptualises AI as a specialised tool that enhances teachers' instructional performance, further research is required to assess the specific AI-related technological knowledge teachers possess.

Fig. 4 details the responses to the Pedagogical Knowledge (PK) indicators from Table 8. The data reveals several areas of concern. About 60% of the respondents selected low-agreement options (options 1 and 2) for item VE01, which indicates a low tendency to use peer observation for learning pedagogical techniques. In the context of teaching an advanced subject like AI, this reluctance could significantly hinder the adoption rate of innovative teaching methods, thereby impacting the quality of learning outcomes. This finding is further corroborated by the responses to item MS07. While nearly 70% of the respondents reported that they actively seek and integrate new AI-related teaching tools and methods, the existence of a significant minority who rarely do so presents a threat to the widespread adoption of best practices in AI education.

Finally, the high percentage of low-agreement responses (about 64–68%) to item MS11 highlights another critical issue. Project-based learning, a key PK competency for AI education as proposed by Kim *et al*. (Table 1), is not being practiced by a majority of the teachers surveyed. As the relationship between project-based learning and TPACK has already been proven in other contexts [42], this is a significant finding for educational policymakers and teacher educators responsible for designing more effective professional development programs.

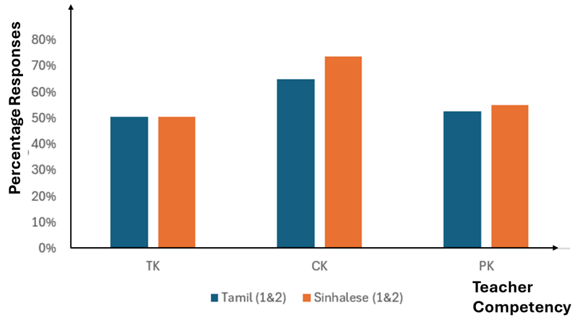

Fig. 4. The response pattern for each Pedagogical Knowledge (PK) indicator.

B. Impact of Teachers' Background on their Knowledge

This study descriptively analysed the relationship between teacher competency and several background variables, including age, ethnicity, gender, school type, length of service, and STEM background. Two primary hypotheses were formulated based on the Sri Lankan educational context.

First, given that national schools in Sri Lanka are reputed to have more resources and a higher quality of education, we hypothesised that teachers in national schools would demonstrate a higher level of competency than their counterparts in other schools. This hypothesis aligns with the established finding that better-resourced schools tend to achieve superior outcomes in critical examinations [43]. Second, as AI is a STEM discipline, we hypothesised that teachers with a degree and a background in STEM would possess a higher competency for teaching AI. For the purpose of this analysis, a teacher's STEM background was determined by their academic stream in the final school-leaving examination. This is a reliable proxy in the Sri Lankan context, as the university major is largely determined by the stream a student follows in this examination.

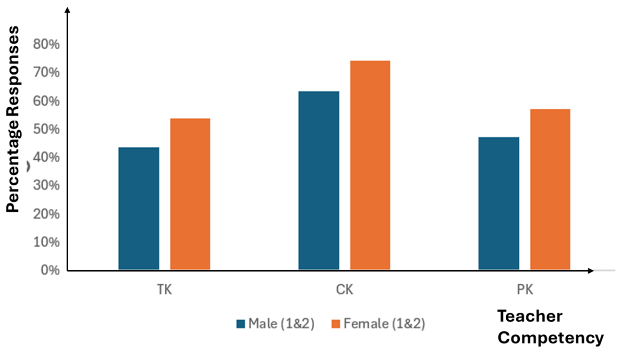

Fig. 5. Age-wise analysis of TK, CK, and PK.

Fig. 5 presents an analysis of teacher knowledge based on age, showing the average percentage of low-agreement responses (Options 1 and 2) for each knowledge type: Technological (TK), Content (CK), and Pedagogical (PK). For each knowledge category (e.g., TK), the responses to the corresponding items were averaged to create a composite score. The data is segmented into four age categories: 21–30, 31–40, 41–50, and 51–60. A primary observation is that a significant deficiency in Content Knowledge (CK) is evident across all age groups. Notably, this lack of content knowledge is slightly more pronounced in the 31–40 and 41–50 age categories. As noted by [19], professional development for AI education often prioritises training on specific AI tools (Technological Knowledge), whereas teachers frequently report a more pressing need for foundational Content Knowledge. This highlights a critical misalignment, as robust Content Knowledge is essential for effective pedagogy and the meaningful integration of both TK and PK in the classroom. Although deficiencies were also noted in technical and pedagogical knowledge, the pronounced lack of content knowledge, hence, is particularly concerning and requires immediate attention.

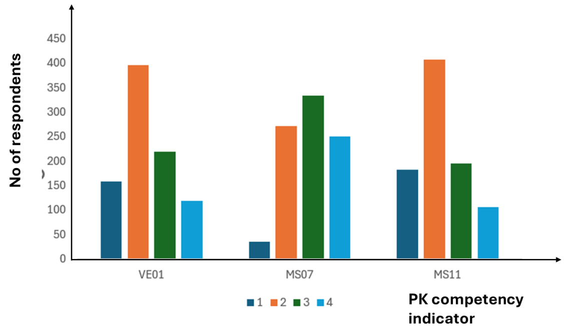

Fig. 6. Ethnicity-wise analysis of TK, CK, and PK.

Fig. 6 presents an analysis of teacher knowledge disaggregated by ethnicity, showing the average percentage of low-agreement responses for each knowledge type. Sri Lanka is a multi-ethnic country, with Sinhalese, Tamil, and Muslim populations. For this analysis, respondents were categorised into two groups: Sinhalese and native Tamil speakers. This grouping was based on the observation that within the ICT teacher community, the vast majority of Muslim teachers are native Tamil speakers.

A key observation from the data is the more pronounced lack of Content Knowledge (CK) among Sinhalese ICT teachers when compared to their Tamil-speaking counterparts. While the underlying reasons for this disparity are not immediately clear, this finding highlights the need for further research to inform the design of targeted teacher training policies and strategies. This finding is particularly consequential from a systemic perspective, as Sinhalese teachers constitute the majority of the country's teaching workforce. This situation warrants further, more nuanced investigation to understand the underlying causes of this knowledge gap, which is an essential first step toward developing effective and tailored professional development programs.

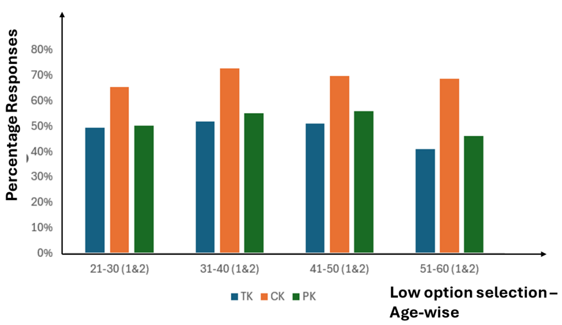

Fig. 7. Gender-wise analysis of TK, CK, and PK.

A gender-based analysis of the average low-agreement responses reveals significant disparities in teacher competencies (Fig. 7). Notably, female teachers reported a substantially lower level of competency across all three knowledge domains: Technological, Pedagogical, and Content Knowledge. These figures reveal a critical professional development gap: nearly three-quarters of female teachers report deficient content knowledge, while more than half report deficiencies in technological and pedagogical knowledge. This situation necessitates immediate and targeted intervention. This finding is particularly critical given that the majority of the teachers in the country are female. Consequently, this competency gap between male and female teachers poses a significant threat to the successful implementation of AI education nationwide.

This finding is particularly noteworthy because it contributes to the ongoing debate surrounding gender disparities in technology use. While many studies suggest that the gender gap in technology adoption has narrowed [44], other research continues to document instances where females are marginalised in specific socio-technical contexts [45]. The discrepancy observed in the findings aligns with this latter perspective and underscores the need for more nuanced, tailored research. Such an investigation is essential to understand the specific factors at play and to guide effective policymaking. Furthermore, it is noteworthy that a significant percentage of male respondents also reported low competency across all three knowledge categories, particularly in content knowledge. This finding is particularly concerning because it challenges the common stereotype of male proficiency with technology.

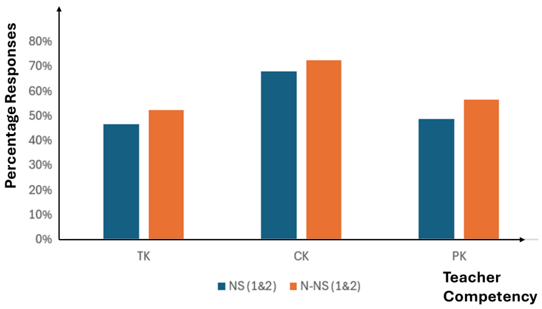

Fig. 8. Type of school-wise analysis of TK, CK, and PK.

The data presented in Fig. 8 confirms the initial hypothesis that teachers in National Schools (NS) possess comparatively higher competencies than their counterparts in non-national schools (N-NS). However, it is surprising to note that the competency gap between these two groups is smaller than anticipated. Moreover, although teachers in non-national schools report slightly lower skills across all three domains, a significant lack of content knowledge is evident in nearly 68-72% of all teachers, regardless of their school type.

From a policy perspective, this finding has two significant implications. First, the relatively low competency levels observed even among teachers in national schools—which are generally better-resourced and have a stronger reputation for quality in Sri Lanka—may indicate a potential underutilization of available resources. This raises significant concerns about whether national schools can fully leverage their advantages to successfully implement the AI curriculum. Second, this finding underscores the necessity of empowering non-national schools across the country to mitigate potential disparities and prevent the widening of a digital divide.

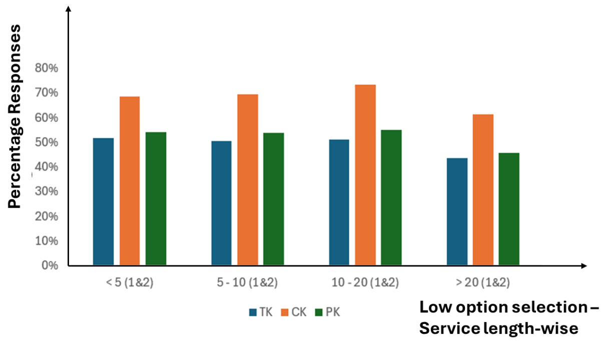

Fig. 9. Service lengthwise analysis of TK, CK, and PK.

While it was acknowledged that length of service might not significantly impact Content Knowledge (CK) due to the novelty of AI in the curriculum, it was anticipated that more experienced teachers would demonstrate superior Pedagogical (PK) and Technological (TK) knowledge.

However, the results presented in Fig. 9 contradict this expectation, indicating that competency levels do not vary significantly with the length of service. Teachers across all service brackets reported a consistently high deficiency in Content Knowledge. This pattern, though less pronounced, also persists for both TK and PK. This finding confirms that a strategic revision of the government's current teacher training approach is necessary. Given that teachers with longer service records have likely participated in numerous training programs, the data raises significant concerns about the actual return on investment and effectiveness of these initiatives.

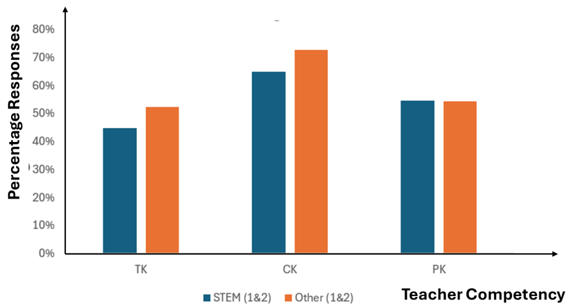

Fig. 10. Type of discipline-wise analysis of TK, CK, and PK.

As AI is a STEM discipline, it was hypothesised that teachers with a STEM background would possess greater competency for teaching the subject. In this study, respondents who held a degree and had followed the Science, Mathematics, or Technology stream for their school leaving examination were categorised as having a STEM background. Fig. 10 presents the proportion of low-agreement responses (options 1 and 2) selected by graduate teachers with a STEM background and others for items assessing their Technological Knowledge (TK), Content Knowledge (CK), and Pedagogical Knowledge (PK).

According to the figure, graduate teachers with a STEM background reported higher TK and CK than the others. However, the difference in these knowledge levels between the two groups was less substantial than anticipated. Moreover, a significant majority—nearly 70%—of STEM-background graduates also indicated a lack of content knowledge. Thus, these results suggest that having a degree and a STEM background is not significantly associated with higher self-assessed TK and CK for teaching AI. This further suggests an untapped potential, where teachers may not fully recognise how the unique thinking patterns and problem-solving methodologies inherent to a STEM background can enhance their teaching capacity.

Prior research indicates that a core benefit of having a STEM background is its influence on an educator's way of thinking, particularly through experiences with practical problem-solving [46, 47]. This insight is especially relevant given our study's finding that teachers rarely adopt project-based learning approaches. This suggests a need for professional development that moves beyond mere tool training to actively cultivate teachers' analytical and problem-solving skills. Addressing this is vital, as teachers' own educational experiences are directly linked to their teaching capacity and, subsequently, to international trends in students' STEM career choices. Investing in such pedagogical shifts could therefore be a highly effective strategy for improving students' AI competencies and fostering a more positive learning environment for AI education.

C. Policy-Level Implications of the Findings

This analysis yields several critical implications for national teacher professional development initiatives. First, the study identifies a pervasive and significant deficit across all three measured domains of knowledge: Technological (TK), Content (CK), and Pedagogical (PK). This deficiency is not isolated to a specific subgroup but is evident across the entire cohort of educators, regardless of demographic and professional variables such as age, gender, ethnicity, length of service, STEM background, or school type. This suggests a systemic issue in teacher preparation and ongoing training rather than challenges confined to particular segments of the workforce. Second, the findings reveal that teachers' Content Knowledge (CK) is markedly lower when compared to their technological and pedagogical knowledge. This is a particularly concerning finding, as robust content knowledge is the fundamental prerequisite for effective instruction. Without a deep understanding of the subject matter, even the most sophisticated pedagogical techniques or technological tools cannot be optimally leveraged, fundamentally limiting the quality of education delivered to students. Third, a noteworthy gender-based disparity was observed. Female teachers, who constitute the vast majority of the current in-service teaching population, demonstrated lower levels of knowledge across all three domains compared to their male counterparts. Given their demographic dominance, this finding indicates that a substantial portion of the educator workforce may require targeted support. Therefore, professional development initiatives must be designed with additional focus and resources to address this specific gap and ensure equitable competency across the profession.

In light of these findings, it is strongly recommended that teacher training and professional development programs be strategically and systematically redesigned. A key recommendation is the adoption of a systems thinking approach to teacher professional development. Prior research emphasises the importance of shifting from linear, product-oriented professional development models [48] toward teacher development systems [49]. Within such systems, multiple subsystems related to teacher learning interact dynamically across different levels [50].

For example, from an ecological perspective, schools can serve as professional development ecosystems [51] where teachers collaborate not only with peers but also with external stakeholders such as industry partners, universities, teacher educators, and students to enhance their learning. Encouraging teachers to become researching teachers who engage in ongoing action research [52] supports the sustainability of education and aligns well with this systems-based approach [53]. Furthermore, establishing industrial and academic mentoring programs would empower teachers to confidently integrate emerging AI technologies and tools into their teaching practices [54]. More recent research corroborates these proposals, indicating that teachers who engage in job-embedded professional development—such as coaching, mentoring, teacher networks, and action research—tend to report higher levels of self-efficacy [55].

V. Concluding Remarks, Limitations, and Future Work

This study sought to address two critical questions regarding the professional development of Sri Lankan ICT teachers for the recent initiative to introduce Artificial Intelligence (AI) in schools. Utilising the Technological Pedagogical Content Knowledge (TPACK) framework, the first research question focused on identifying the existing knowledge gaps—specifically in Technological (TK), Content (CK), and Pedagogical (PK) knowledge—among in-service ICT teachers. The second question investigated the impact of teacher background variables (including age, gender, ethnicity, length of service, STEM background, and school type) on their TK, CK, and PK.

The research involved a secondary analysis of a pre-existing dataset collected via a questionnaire originally designed to assess teachers' self-efficacy for teaching AI, grounded in Bandura's theory. To align with the study's framework, items from the self-efficacy scale were mapped onto the TK, CK, and PK dimensions of TPACK, using a published and validated questionnaire as a reference. The instrument's construct validity was evaluated using a sequential Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Following the validation of the factor structure, the internal consistency reliability of each subscale was assessed. Furthermore, benchmark standards for the required content knowledge (CK) to teach AI in schools were established through a review of the relevant literature.

Beyond its specific recommendations for Sri Lankan policymakers, this study offers several contributions to the broader international community. Methodologically, it demonstrates a practical approach for leveraging secondary data to assess teacher readiness, a valuable model for contexts with limited research resources. Substantively, it provides a foundational benchmark for evaluating teachers' AI-related Content, Pedagogical, and Technological Knowledge (CK, PK, TK) that can be adapted by other nations. Finally, this research opens clear avenues for future inquiry, particularly studies that investigate the more complex, integrated elements of the TPACK framework within the emergent domain of AI education.

This study, like any, has certain limitations that should be acknowledged. The primary limitation arises from the use of a secondary dataset. The data were originally collected using an instrument designed and validated to measure teacher self-efficacy, not the Technological Pedagogical Content Knowledge (TPACK) framework directly. While the items were carefully mapped to the TPACK constructs of TK, PK, and CK, and validated statistically, a study employing a questionnaire specifically designed to evaluate the TPACK framework for AI education would likely yield more direct and robust insights.

Furthermore, the current analysis is confined to the three primary knowledge domains: Technological (TK), Pedagogical (PK), and Content (CK). It does not extend to the critical integrated—or intersectional—domains of Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). A comprehensive assessment of teacher readiness for technology integration necessitates an analysis of these integrated elements, as they represent the true synthesis of knowledge required in a modern educational setting.

Another notable limitation of this study lies in its reliance on a descriptive analytical approach. While descriptive statistics and visualisations provided valuable insights into teachers' self-perceived knowledge levels across the TPACK domains, this approach does not capture the potential interactions among multiple background variables. Future studies could employ multivariate statistical techniques, such as multiple regression analysis, structural equation modelling (SEM), or multigroup analysis, to examine the collective and differential impact of demographic and contextual factors on teachers' Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Moreover, exploring mediating or moderating effects of background characteristics (e.g., teaching experience, subject area, school type) through latent variable modelling or path analysis could yield deeper insights into how these factors shape teachers' AI-related competencies. Such approaches would enhance the explanatory power and generalizability of future findings beyond the descriptive level.

Another limitation of this study is the insufficient coverage of the ethical and societal dimensions of AI as emphasized in the AI-TPACK [17] framework. Given the rapid integration of AI into various aspects of daily life, teachers' understanding of these dimensions is crucial for fostering students' awareness of the responsible and ethical use of AI systems. Future studies should therefore incorporate measures that more comprehensively assess teachers' competencies in addressing the ethical, social, and human implications of AI technologies.

Despite these constraints, this study provides a valuable foundational analysis. It serves as a crucial preliminary report, bringing to light previously undocumented findings regarding teacher knowledge levels in Sri Lanka to teach AI and, significantly, identifying the impact of various background variables on these competencies. The insights generated here lay the groundwork for more targeted and comprehensive research. Future work will be designed to directly address these limitations by employing a validated TPACK instrument to conduct a holistic analysis that includes all seven domains of the framework. Another promising direction for future research is the use of computational modelling and simulation to investigate teacher learning and professional development from a complex systems perspective.

Conflict of Interest

The author declares no conflict of interest.

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