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Teachers' perceptions, attitudes, and acceptance of artificial intelligence (AI) educational learning tools: An exploratory study on AI literacy for young students

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Abstract

Artificial intelligence (AI) literacy education for young students is gaining traction among researchers and educators. Researchers are developing courses and attempting to teach AI literacy to younger students, using age-appropriate AI educational learning tools. Although teachers play a crucial role in AI literacy education, their perceptions and attitudes have received little attention. This study explores the perceptions of 60 teachers regarding the use of AI educational learning tools, and examines the factors influencing their attitudes in relation to implementing AI literacy education. The technological acceptance model and the technological, pedagogical, and content knowledge (CK) (TPACK) framework inform the research design, and a mixed method, combining the statistical package for Social Science and thematic analysis, is employed for data analysis. The study reveals that teachers have positive perceptions regarding the usefulness and ease of use of AI educational learning tools in their AI literacy teaching. This paper also reveals that teachers embrace an arts-based approach to teaching AI literacy. The qualitative data reveal that teachers face challenges such as insufficient CK and experience with AI; and knowledge of TPACK. The five factors affecting their acceptance of AI educational learning tools are: (a) teachers' perceptions of their AI CK and experience in teaching AI literacy (technological content knowledge); (b) technical challenges and stakeholder acceptance; (c) the attributes of AI educational learning tools; (d) school infrastructure and budget constraints; and (e) potential for distraction and negative emotional responses. This study offers insights for policymakers regarding

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professional development initiatives and technical support mechanisms, thereby facilitating more effective AI literacy implementation.

KEYWORDS
AI educational learning tools and platforms, AI literacy education, artificial intelligence (AI) early childhood and primary education, the arts-based pedagogy, the technological pedagogical content knowledge (TPACK) framework, the technology acceptance model (TAM)

1 | INTRODUCTION

Artificial intelligence (AI), as an emerging subfield of computer science (Yau et al., 2022), is recognized as one of the most influential technologies ever developed, with the continuous progress of its capabilities deemed inevitable (Russell, 2021). The term AI refers to the use of computers that can simulate human intelligence through technological innovation (Russell & Norvig, 2010), such as machine learning, deep learning, and neural networks (Aggarwal, 2018).

The importance of fostering AI literacy has increased as AI has become integrated into many aspects of our lives, having a far-reaching impact on society (Ali et al., 2019; Touretzky et al., 2023). AI literacy teaching in the 21st century is becoming an increasingly popular topic among researchers and educators (Chiu et al., 2021; Ng et al., 2023), with many arguing that AI literacy is now essential for all individuals (Kandlhofer et al., 2016; Long & Magerko, 2020). There is widespread support for implementing AI literacy education at an early age (Laupichler et al., 2022; Touretzky et al., 2023), and some advocate collaboration between humans and AI as a means to improve educational outcomes for students (Luckin & Holmes, 2016; Wegerif & Major, 2023; Yim, 2024a).

Some researchers have emphasized the importance of preparing teachers to teach AI literacy to young students at kindergarten and primary school level (Chiu et al., 2023; Dai et al., 2024; Su & Yang, 2022; Yim, 2024b). For example, Kim and Kwon (2023) explore the AI competencies of primary school teachers, and reveal that educators need to gain AI literacy to use AI educational learning tools pedagogically. Edwards et al. (2018), on the other hand, find that teachers should acquire the skills to select and design AI educational learning tools and technological instructions as well as offer emotional and cognitive support to students when using robotic AI educational tools in classrooms. However, it has been reported that some teachers hardly use AI educational tools in their classroom (Choi et al., 2023) due to their cost, their limited application in activities, a lack of teacher training, and the lack of inclusivity in the design of educational tools (Johal et al., 2018).

As countries worldwide enter the era of AI education, there is an increasing demand for teachers' AI literacy and their knowledge of AI educational technologies (Cheng & Yim, 2024; Liu et al., 2023). However, despite calls to teach AI literacy to young students, there has been little research into the perceptions and attitudes of teachers regarding the use of AI educational tools for AI literacy education (Sperling et al., 2024). Research has demonstrated that the adoption of technological tools relies on user acceptance (Kelly et al., 2023; Scherer et al., 2019). As teachers are the major stakeholders in AI literacy education, their favorable attitudes toward AI educational tools is likely to enhance their working efficiency and teaching competency (Chiu, 2024; Yau et al., 2022).

This study adopts the technology acceptance model (TAM), which is used to predict the factors that may positively or negatively influence the acceptance of technology (Davis, 1989). It also uses the technological pedagogical content knowledge (PCK) (technological, pedagogical, and content knowledge (TPACK)) framework, which can help researchers to understand teachers' knowledge of technology, pedagogy, and content in order to support teachers in creating an engaging learning environment for effective teaching (Chai et al., 2013). Utilizing the TAM model and TPACK framework, this study investigates teachers' acceptance of AI educational learning tools and their perceptions regarding the implementation of AI literacy education for young students. Focusing on kindergarten 3 and

primary-level education within the Chinese educational system (equivalent to Key Stage 1 and Key Stage 2 in the United Kingdom national curriculum, for students aged between five and 11), the study seeks to provide insights that can inform the planning of professional development initiatives and pedagogical strategies, and ultimately increase the effectiveness of AI literacy implementation.

2 | LITERATURE REVIEW

2.1 | AI, AI in education (AIED), and AI literacy education

AI involves machines performing tasks that would require intelligence if performed by humans (Russell & Norvig, 2010). When AI is applied to education, it is referred to as AIED (Wegerif & Major, 2023). The fields of AIED, which include teaching with AI, and AI literacy education, which is focused on teaching and learning about AI, often intersect. In other words, AI can be utilized as a technological tool to support teachers in educational contexts or as an educational tool that teachers can use to help students understand AI algorithms and AI literacy (Chounta et al., 2022; Yim & Su, 2024).

AIED integrates AI technologies in educational settings to enhance teaching and learning processes. These technologies include intelligent tutoring systems, personalized learning platforms, data analytics for predicting student performance, and automated grading systems (Luckin & Holmes, 2016). In contrast, AI literacy education requires educators to possess comprehensive knowledge of teaching content, as well as of the technology and pedagogy necessary to effectively teach students about AI concepts (Celik, 2023).

AI literacy is "a set of competencies that enables individuals to critically evaluate AI technologies, communicate and collaborate effectively with AI, and use AI as a tool online, at home, and in the workplace" (Long & Magerko, 2020, p. 2). Although AI is ubiquitous in daily life and the workplace, many people acknowledge the existence of AI without understanding the basic concepts and principles behind AI technologies (Ali et al., 2019; Touretzky et al., 2023). Many researchers have proposed the need for AI literacy education (Su & Yang, 2022; Yim, 2024a) on the basis that AI literacy is a new literacy skill as important as reading and writing (Kandlhofer et al., 2016). They have argued that students must learn AI literacy in order to fully participate in a world increasingly influenced by AI (Kong et al., 2024) and apply AI knowledge and tools to solve problems in real-life settings (Ali et al., 2019).

Initially, AI literacy was exclusively taught to university students in computer science and engineering courses (Laupichler et al., 2022), before being extended to some secondary school students (Chiu et al., 2021; Touretzky et al., 2023). However, with more age-appropriate AI educational tools and technologies being developed (Yim & Su, 2024), governments and researchers have started to explore AI literacy education for young students in early childhood and primary school settings (Su et al., 2022; Yim, 2024a). Teaching AI literacy encompasses more than simply preparing students to understand and use AI in their future careers (Kandlhofer et al., 2016). It also involves fostering an understanding of AI ethics to promote social responsibility and inclusivity (Walsh et al., 2023; Zhang, Lee, et al., 2023), as well as nurturing students' AI thinking (Yim, 2023; Yim, 2024a) and creative mindset (Ali et al., 2019; Long et al., 2023). As a result, many scholars advocate integrating AI literacy education from the earliest educational stages (Heintz, 2021), emphasizing that AI literacy is essential for all individuals to become responsible AI citizens (Yim, 2023), regardless of their background in computer science (Chiu et al., 2021).

2.2 | Educators' views on AI literacy education

AI literacy has already been introduced in various national curricula (Pedro et al., 2019), particularly targeting early childhood and primary education (Su & Yang, 2022; Touretzky et al., 2023). United

Nations Educational Scientific and Cultural Organization has identified AI literacy teaching to young students as a significant new challenge for global school education (Chiu, 2024). Educators and teachers are often identified as key architects responsible for shaping future educational systems that incorporate AI literacy education (Ayanwale et al., 2024; Chiu, 2024). However, there is a significant lack of initiatives aimed at training educators in AI literacy (Sperling et al., 2024).

Educators are required to develop not only technological and pedagogical strategies (Ayanwale et al., 2024), but also acquire fundamental knowledge and skills to understand, create, use, apply, and evaluate AI applications to deliver content effectively within an educational context (Wilton et al., 2022). They play a crucial role in shaping students' AI literacy and competency development (Chiu & Sanusi, 2024; Yue et al., 2024), providing them with opportunities to learn about AI and empowering them with building their conceptual understanding of AI's ethical considerations (Kong et al., 2023; Touretzky et al., 2023).

While recent research highlights the importance of understanding teachers' attitudes and experiences to enhance the sustainable teaching of AI literacy (Lin et al., 2022), their readiness and preparedness to teach AI literacy are often under-explored (Yue et al., 2024). Educators face significant challenges in teaching AI literacy, including understanding AI's capabilities, limitations, and ethical considerations, along with developing effective pedagogical skills (Ayanwale et al., 2024; Vartiainen et al., 2020). Furthermore, effective AI literacy education demands an understanding of the practical realities of the integration of AI educational learning tools in schools (Han et al., 2024). In addition, many educators lack clear guidance on how to teach AI (Chiu & Sanusi, 2024), which reduces their confidence to teach it (Su, 2024).

Despite the existence of an increasing literature seeking to understand educators' views about AI literacy, the requirements for effectively teaching AI literacy to young students remain poorly understood (Moura & Carvalho, 2024). A survey of 140 K-12 teachers in Estonia revealed that while teachers see AI as an educational opportunity, they have limited AI knowledge and practical application skills (Chounta et al., 2022). Kim and Kim (2022) reveal that teachers view technology negatively and feel discomfort in using it in their classrooms. Similarly, Su (2024) reveals that many teachers report a lack of confidence in their understanding of technology because they often lack access to relevant knowledge of TPACK (Su et al., 2022). Schiavo et al. (2024) highlight the interplay among acceptance, literacy, and anxiety regarding AI technologies, emphasizing that this interplay has a significant effect on teachers' ability to teach AI literacy.

2.3 | Educational use of AI for young students

In recent years, the use of AI educational learning tools has gained significant attention (Yim & Su, 2024). Previous studies have demonstrated that the use of AI educational learning tools and applications, such as Popbot (Ali et al., 2019; Williams et al., 2019), ChatGPT (Jauhiainen & Guerra, 2023; Liu et al., 2023), Google Teachable Machines (Toivonen et al., 2020; Vartiainen et al., 2020) and Doodlebot (Williams et al., 2024) can support young students in their AI literacy learning (Yim & Su, 2024). For example, Williams et al. (2019) have examined how PopBots can be utilized as an educational tool to introduce kindergarten students to AI concepts through social interaction, while Ali et al. (2019) have used PopBots as a programmable artifact and guide for primary school students. Melsión et al. (2021) have explored the use of Google's Teachable Machine to allow primary school students to explore machine learning while raising their awareness of algorithmic and gender bias. There has also been research into using block-based programming AI extensions such as Scratch (Shamir & Levin, 2021) to teach young students AI. Research has indicated that young students who interact with AI educational tools can build their conceptual understanding of AI ethics (Melsión et al., 2021) and AI concepts such as neural networks (Shamir & Levin, 2021), and develop their computational thinking and coding skills (Dai et al., 2023).

Although AI educational tools can support students' learning at a scale previously unimaginable (Luckin & Holmes, 2016; Wegerif & Major, 2023), and the trend of using AI educational technologies is growing, there have been limited attempts to understand teachers' experience and expectations regarding the effective implementation of AI literacy education (Holmes et al., 2023; Luckin et al., 2022). It is important to understand teachers' perceptions of AI literacy and what drives their acceptance of AI, in order to identify the support they need to enhance the effectiveness of their use of AI educational tools.

2.4 | Pedagogies in AI literacy education

As AI has transformed the implementation of instructional pedagogy (Luckin et al., 2022; Wegerif & Major, 2023), extensive research has explored how the strength of humans and AI can be combined in educational settings (Chen et al., 2020). Meanwhile, definitions of AI literacy and AI competency have evolved over time (Chiu & Sanusi, 2024; Long & Magerko, 2020). Traditional AI literacy focuses on the acquisition of knowledge and skills, whereas AI competency extends beyond these to include attitudes, beliefs, and self-reflective mindsets (Chiu & Sanusi, 2024). This broader definition recognizes the holistic development required for individuals to effectively engage with AI technologies (Ayanwale et al., 2024). It highlights the need for AI literacy to be transdisciplinary (Chiu, 2024; Yim, 2024a), incorporating not just technical knowledge but also an understanding of ethical and societal implications (Touretzky et al., 2023). To address these broader implications, advocates of this holistic approach argue for the inclusion of linguistics, philosophy, and other disciplines into AI literacy education (Aliabadi et al., 2023). As a result, pedagogical approaches to teaching AI literacy have been varied.

One of the challenges faced by AI educators is the transmission of AI knowledge to young students in an age-appropriate and engaging manner (Yang, 2022). Previous research has indicated that AI learning content can be taught through project-based (Kong et al., 2024), game-based (Du & Wang, 2023), and collaborative learning approaches (Toivonen et al., 2020; Vartiainen et al., 2020). These methods are well-documented and have shown some effectiveness in differing contexts (Yim & Su, 2024).

In addition, Laupichler et al. (2022) argue that educators have not fully acknowledged the interdisciplinary nature of AI when teaching AI literacy, and Yim and Su (2024) point out that an arts-based approach is often absent in AI literacy education. Arts-based approach is an educational approach that integrate various art form such as visual arts and drama into the learning process (Bayley, 2018) to support and enhance students learning outcomes (Moreno et al., 2023). As recent research has provided evidence that the introduction of arts in transdisciplinary or interdisciplinary education can develop students' subject knowledge, problem-solving (Kim & Kim, 2016), thought process (Bureekhampun & Mungmee, 2020), computational (Chaldi & Mantzanidou, 2021) and programming skills (Sullivan & Bers, 2018), there have been calls to explore innovative pedagogical methods in AI education (Luckin & Holmes, 2016).

Furthermore, a significant debate in the field centers around the potential of AI to widen the digital divide in education (Luckin & Holmes, 2016). Miao et al. (2021) highlight both the opportunities and challenges associated with the use of AI in education. While AI has the potential to democratize education, it might also exacerbate inequalities and limit accessibility for underprivileged students who lack access to AI educational technologies, including those aimed at promoting gender equality. This concern is particularly relevant in the context of AI literacy education, where opportunity, social, and digital inequities can impede equitable access to AI educational learning tools and resources (Farahani & Ghasemi, 2024). Critics of techno-solutionism (i.e., the idea that technology can provide straightforward solutions to complex problems), such as Bulathwela et al. (2024), argue that relying solely on technology to solve educational challenges can lead to a misallocation of resources and fail to address the underlying causes of educational inequality. While

there are many AI educational learning tools available for AI literacy education (Yim & Su, 2024), few are appropriate for young students without programming experience or for resource-constrained classrooms, and they often fail to cover a broad range of AI topics (Williams et al., 2024), which limits the scope of AI literacy education. Diverse and innovative pedagogical methods may help bridge the digital divide by providing multiple entry points for learning (Luckin & Holmes, 2016).

3 | THEORETICAL FRAMEWORK

This study employs the TAM to structure the teachers' surveys and utilizes the technological PCK (TPACK) framework to formulate focus group statements for discussion. This theoretical framing approach aims to understand teachers' acceptance of AI educational tools in their AI literacy teaching as well as investigate how teachers teach AI using technological PCK. To extract concepts from the data, the TAM of Fred Davis (1989) and the TPACK framework (Koehler & Mishra, 2009) serve as the theoretical basis for both the research design and the data analysis of this study (Appendices A and B).

On one hand, the TAM has been extensively employed as a key model for understanding the factors influencing teachers' acceptance or rejection of various kinds of technology in educational settings (Scherer et al., 2019; Zhang, Schießl, et al., 2023). As shown in Figure 1, the two core variables within the TAM, which are ease of use and perceived usefulness (i.e., the acceptance of its benefits), have consistently been identified as key determinants influencing the acceptance of technology in educational contexts (Granić & Marangunić, 2019). Given that AI is rooted in computer science and technology, the application of the TAM within the realm of AI literacy education can provide a valuable framework for examining the dynamics of AI technology acceptance.

On the other hand, the TPACK framework, which is divided into technological content knowledge (TCK), PCK, and CK, could clarify the knowledge teachers need to integrate AI educational tools into their teaching of AI literacy (Celik, 2023). This framework, which aligns with the technological and pedagogical aspects of AI (Ning et al., 2024), allows the study to investigate teachers' competencies in integrating technology into their teaching instructions (Mishra & Koehler, 2006).

Twelve TPACK framework statements relevant to teaching AI literacy have been adapted and modified from Kong et al. (2023), covering TCK (e.g., "*I can choose appropriate images and tools to train and build datasets in Teachable Machine*"), PCK (e.g., "*Without using technology/a computer, I know how to select effective teaching approaches to guide students in thinking about and learning AI*"), CK (e.g., "*I have sufficient knowledge of AI*"), and integrated TPACK knowledge (e.g., "*I can design and teach lessons that appropriately combine AI, technologies, and teaching approaches*"). These statements serve as the basis for eliciting insights into educators' perspectives on the critical

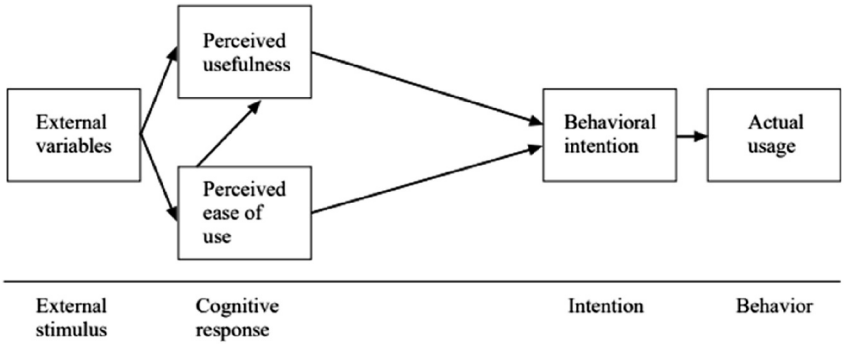

FIGURE 1 The technology acceptance model (Venkatesh & Davis, 1996).

components of AI literacy education. The survey also contained a question regarding pedagogy: Whether teachers limit themselves to using technological pedagogies or if they also consider the pedagogical appropriateness of various methods, such as arts-based approaches, when teaching AI literacy to young students.

4 | THE DEFINITION AND FOCUS OF AI EDUCATIONAL TOOLS FOR THIS STUDY

AI educational tools in this study refer to learner-facing tools that teachers use to teach AI literacy concepts to young students. AI educational tools can be used in various ways (Luckin et al., 2022). According to Baker and Smith (2019), such tools can be divided into three categories: system-facing, teacher-facing, and learner-facing. System-facing tools provide information for administrators and managers at the institutional level, aiding in decision-making and management. Teacher-facing systems are designed to support educators by reducing their workload and enhancing their teaching capabilities. Learner-facing AI tools, on the other hand, are used by students for subject matter learning and are central to AI literacy education. These tools include intelligent agents, social robots like PopBots, and machine learning systems such as Google Teachable Machine.

5 | RESEARCH GAPS AND RESEARCH QUESTIONS

This study identifies three gaps in the literature. First, although there is a compelling case for introducing AI literacy into early years and primary school education, there has been little research on how to do so effectively. Second, while the role of AI educational tools has been deemed pivotal in AI literacy educational settings and teachers have been regarded as stakeholders playing a significant role in deciding on the use of AI educational tools, there has been little research on teachers' attitudes to this new technology. Third, there is an insufficient amount of research regarding the issue of teachers' acceptance of using and integrating AI educational tools into their teaching practice, along with their perception of AI literacy education implementation for young students.

Understanding teachers' attitudes and perspectives is critical for effective AI literacy education implementation. It not only informs the planning of implementation strategies but also guides professional development initiatives, shapes pedagogical approaches, influences resource allocation decisions, and ultimately contributes to enhanced student learning outcomes. Therefore, five research questions are formulated.

RQ1: How do teachers perceive the ease of use and usefulness of AI educational learning tools in their AI literacy education for young students?
RQ2: What are teachers' perceptions of pedagogical strategies in AI literacy education?
RQ3: What are teachers' understanding of educational content related to "AI literacy"?
RQ4: What factors influence teachers' attitudes toward the use of AI educational learning tools in AI literacy education for young students?
RQ5: What types of support do teachers perceive as necessary to enhance the implementation of AI educational learning tools in AI literacy education?

6 | METHODOLOGY

Both qualitative and quantitative data were adopted to triangulate this study (Creswell, 1999). First, demographic information about the teacher participants was collected. Second, two surveys were designed and a small focus group discussion was conducted. The first survey, adapted from

Khanlari (2016) and modified by the researchers of this study, consisted of 27 multiple-choice questions and two open questions to explore teachers' CK about AI literacy (see Appendix A). These multiple choice questions were designed to identify teachers' perceptions regarding ease of use (e.g., "*Easy and convenient to facilitate teaching"*) and usefulness (e.g., "*Enhance students' AI knowledge*"), as well as potential factors that might affect teachers' attitudes toward the use of AI educational tools, such as technological knowledge (e.g., "*Lack of teachers' knowledge and information about how to use and operate AI technology*"), pedagogical strategies ("*Do you agree on the need to use the arts to teach children AI literacy?*"; "*Do you agree on the need to use AI educational learning tools such as social robots to teach children AI literacy?*"). Each item was based on a 5-point Likert scale with 1 indicating "Strongly Disagree" and 5 indicating "Strongly Agree". Statistical package for Social Science was used to analyze descriptive statistics. These 27 multiple choice questions were validated with a Cronbach's alpha of 0.655, which indicates an acceptable level of consistency and reliability in the survey questions. Meanwhile, open questions were also asked to understand teachers' CK (e.g., *"From your understanding, describe what you think AI literacy means to you"*; *"What do you wish to be added to your current curriculum/program regarding AI literacy learning and teaching?"*).

The second survey contained three open questions to understand teachers' attitudes toward AI literacy education and the types of support they perceive as necessary in teaching AI literacy to young students (e.g., "*What do you think about AI literacy education implementation in Hong Kong? Any difficulties and challenges?*"; "*What* support *do you feel is needed to help you?"; "What would you be most worried about if an AI learning program were implemented for young students in Hong Kong?"*). Thematic analysis was used to code the data and discern any key themes and patterns that emerged from the dataset (Braun & Clarke, 2006) (Appendix C).

Both surveys were distributed based on convenience sampling, facilitated through the established connections with Chinese schools of one independent researcher, one teacher, and one retired school principal. To further explore teachers' understanding of AI literacy, the researchers of this study organized a focus group consisting of three primary school teachers from a single school that had not previously implemented AI interventions. The focus group discussion was facilitated by employing the diamond ranking method (Figure 2), a visual tool commonly used in educational research (Clark, 2012) to promote collective decision making, prioritize educational objectives, and facilitate discussion and debate to understand different concepts and perspectives. Adapted from Kong et al.'s (2023) TPACK survey adopted in teachers' development programs for primary schools, this study used 12 statements as a collaborative strategy to help this focus group prioritize and organize their thoughts (Appendix B). It involved teachers arranging nine statements in a diamond shape based

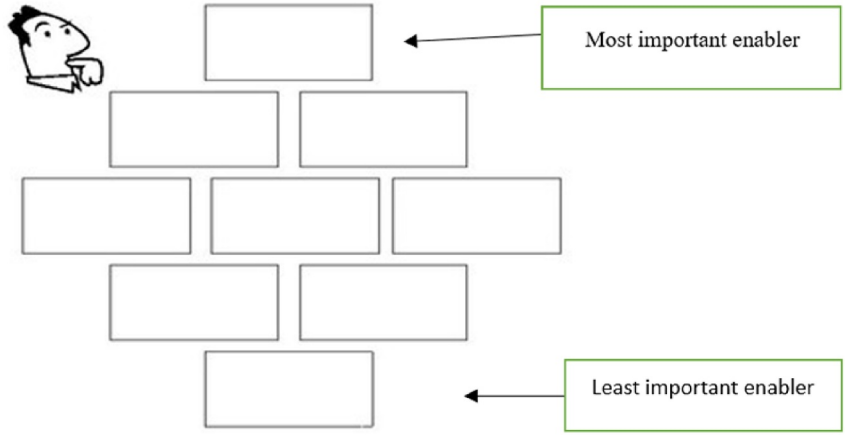

FIGURE 2 Diamond Nine Method modified and adapted in focus group discussion (Clark, 2012).

on their agreed-upon importance or relevance. Dialogs generated from this focus group were audio-recorded, and transcriptions were sent to the three teacher participants for verification.

6.1 | Participants

The various survey links were distributed to teachers in two kindergartens and two primary schools in the Chinese education system. Participants were informed of the purpose of the study and gave informed consent before completing the survey.

Data from all participants who agreed to use their information for research purposes are included in this study. A total of 60 teachers participated voluntarily, of whom 60% participated in the survey with 27 multiple questions, 35% participated in the survey with three open questions, and 5% participated in the focus group discussion. As shown in Figure 3, 72% of the participants were female teachers, 27% were male teachers, and 1% preferred not to disclose their gender. Overall, 8% of the participants had received professional development in AI (5 out of 60) and 92% had not.

7 | FINDINGS

7.1 | RQ1: How do teachers perceive the ease of use and usefulness of AI educational learning tools in their AI literacy education for young students?

Overall, teachers' perception of the ease of use and usefulness of AI educational learning tools are positive, as shown in Table 1. In terms of ease of use, 33 teachers out of 36 (92%) agreed that AI educational learning tools are easy and convenient to use. In terms of teachers' perceptions of the usefulness of AI educational learning tools, the most reported usefulness by teachers was that AI educational learning tools could enhance students' AI knowledge, save teaching time, and allow teachers to spend more time on students and their learning. For example, on the one hand, teachers perceived that the use of AI educational learning tools would enhance students' learning outcomes in terms of (a) acquiring AI knowledge (Q18 mean = 4.22, s.d. 0.422), constructing new knowledge with AI (Q21 mean = 4.03, s.d. 0.026), and correcting misconceptions about AI (Q20 mean = 3.81, s. d. 0.577); (b) developing skills such as cognitive thinking (Q13 mean = 4.11, s.d. 0.622), communication, social skills (Q12 mean = 4.06, s.d. 0.475), and creativity (Q17 mean = 4.03, s.d. 0.377); and (c) developing appropriate behaviors (Q16 mean = 4.11, s.d. 0.523), such as how to interact with AI (Q19 mean = 4.06, s.d. 0.475). On the other hand, teachers perceived that the usefulness of AI educational tools lied in their enhancement of teaching efficiency and effectiveness, such as through time-saving (Q14 mean = 4.17, s.d. 0.655), workload reduction (Q8 mean = 4.08, s.d. 0.28), and providing valuable alternative tools (Q11 mean = 4.03, s.d. 0.377) in their teaching practice.

7.2 | RQ2: What are teachers' perceptions of pedagogical strategies in AI literacy education?

Based on the quantitative data from the survey 1 with multiple choice questions, a frequency analysis of teacher participants' responses showed that 94% agreed that it is necessary to teach AI literacy to primary school students. The majority (97%) reported that they endorse and accept the use of AI educational tools to teach students, whereas 88% reported that they also agree with the use of the arts-based approach to teach AI literacy (Figure 4 shows these results graphically). The results of this study indicate that teachers have a positive attitude toward teaching AI literacy to young students. It also reveals that teachers endorse the use of AI educational technologies and embrace other non-technological pedagogies, such as arts-based approaches to teaching AI literacy to young students.

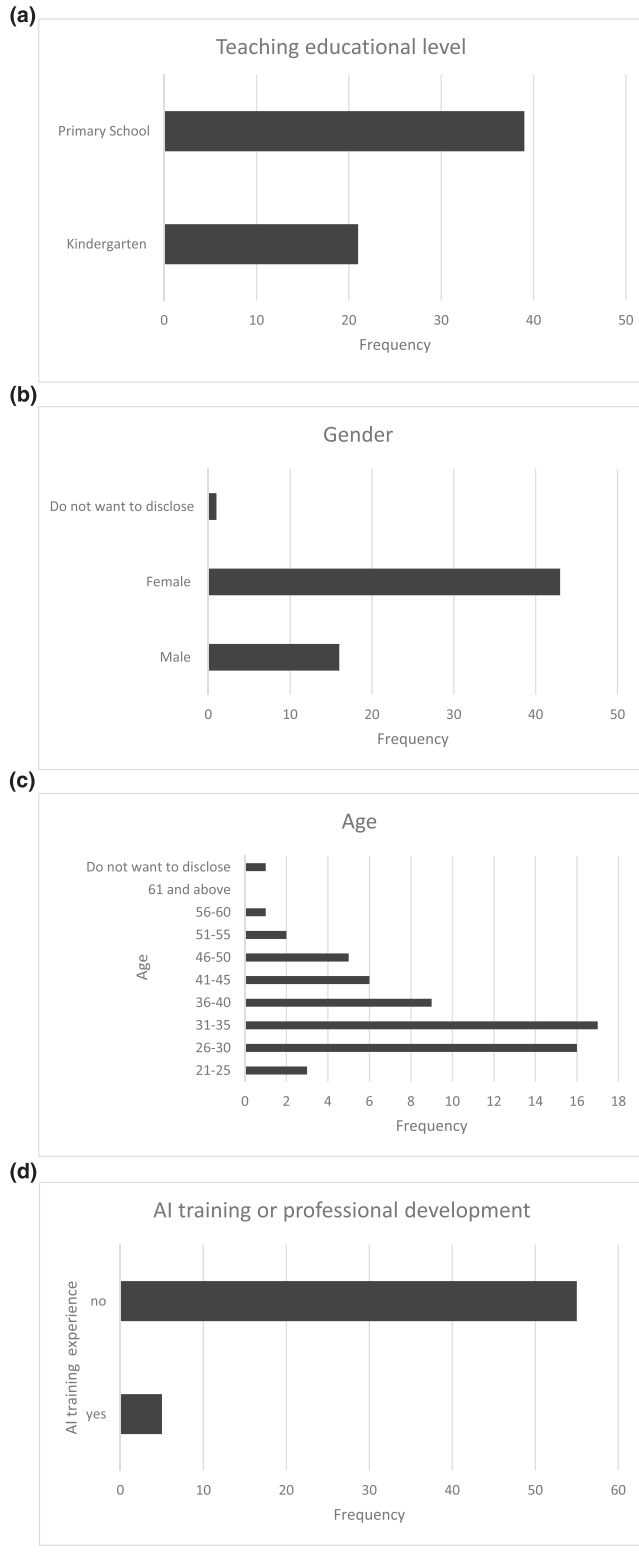

FIGURE 3 Frequency tables of teacher participants. (a) Teaching educational level. (b) Gender. (c) Age. (d) AI training or professional development.

TABLE 1 Descriptive statistics for the ratings of items on perceptions of the usefulness and ease of use of artificial intelligence (AI) educational tools.

Theme	Item	Mean (S.D)	95% confidence interval	
			Lower	Upper
Perception about ease of use	Q9. Easy and convenient to facilitate teaching	4.17 (0.561)	3.98	4.36
Perceptions of the usefulness	Q18. Enhance students' AI knowledge	4.22 (0.422)	4.08	4.36
	Q14. Save teaching time	4.17 (0.655)	3.95	4.39
	Q15. Allow teachers to spend more time on students and their learning	4.17 (0.447)	4.02	4.32
	Q13. Develops cognitive thinking, skills, and abilities	4.11 (0.622)	3.90	4.32
	Q16. Promotes and helps students to develop appropriate behaviors	4.11 (0.523)	3.93	4.29
	Q8. Reduces teacher workload	4.08 (0.28)	3.99	4.18
	Q12. Develops communication, language, and social skills	4.06 (0.475)	3.89	4.22
	Q19. Promote students about how to use and interact with AI and develop their AI skills	4.06 (0.475)	3.89	4.22
	Q11. Is an alternative tool to enhance students' learning	4.03 (0.377)	3.90	4.16
	Q17. Promote the creativity of students	4.03 (0.377)	3.90	4.16
	Q21. Construct new knowledge with AI	4.03 (0.028)	3.97	4.08
	Q10. Enhance students' class participation and engagement	4.00 (0.414)	3.86	4.14
	Q20. Correct students' misconceptions about AI	3.81 (0.577)	3.61	4.00

Note: Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

7.3 | RQ3: What are teachers' understanding of educational content related to "AI literacy"?

The brevity and simplicity of the responses to the open questions in Survey 1 (Table 2), responding by describing AI literacy merely as "AI", indicates that many teachers may have a limited understanding or lack confidence in discussing what AI literacy truly entails. Of the 36 teachers who answered the first open question, 25 described AI literacy as "AI", 10 described it as learning with and about AI, and one as AI knowledge. Meanwhile, none responded to the question, "*What do you wish to be added to your current curriculum/program regarding AI literacy learning and teaching?*" This might indicate a potential lack of engagement or confidence regarding the subject.

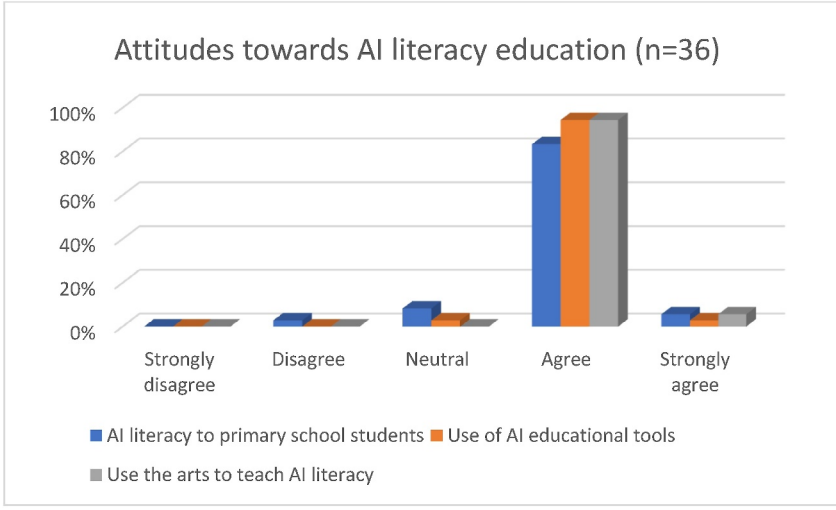

FIGURE 4 Attitudes of teacher participants.

TABLE 2 Content knowledge (CK) of teacher participants.

Survey 1- about content knowledge		***N* =**
Question	Q7: Describe what artificial intelligence (AI) literacy means to you.	
Response	"AI"	$N = 25$
	"Learn about AI, learn with AI"	$N = 10$
	"AI knowledge"	$N = 1$
Question	Q37: What do you wish to be added to your current curriculum/program regarding AI literacy learning and teaching?	
Response	No reply from teachers	$N = 0$

However, qualitative data from a follow-up focus group reveal that at least three teachers demonstrated a much deeper understanding of AI literacy. In response to the question "What is AI?", these three teachers demonstrated a good basic understanding of AI in four areas, namely the definition of AI, the features of AI, AI examples, and non-AI examples. Their responses are as follows.

Definition of AI: The teachers collectively agreed that AI simulates or mirrors the human learning process, and is not merely confined to pre-set rules. Teachers stated that:

> *AI can operate beyond traditional programming, relying instead on analyzing millions of data samples to learn. An example of this learning is a chess-playing AI that uses data and reinforcement learning to strategize and improve, rather than following a fixed set of rules.*

Features of AI: Four features were identified: machine learning, reinforcement learning, big data, and self-improvement. Teachers agreed that:

> *Machine learning is the ability of AI to learn from data without explicit programming. Reinforcement learning is a type of machine learning where AI learns to make decisions by using a lot of data for self-learning. While AI systems require vast amounts of data to learn effectively, and therefore have big data dependency, self-improvement is important for AI as it is the capacity of AI to autonomously learn new things and enhance its performance over time.*

Examples of AI: The teachers identified ChatGPT, AI-generated arts, and Scratch with AI extensions as examples of AI.

Non-Examples of AI: Teachers gave one non-example of AI: the standard Scratch programming tool, a basic coding platform without AI features. At the same time, they agreed that, with AI extensions, Scratch could be used to teach students AI literacy.

Overall, the qualitative data reveal that the three teachers had a good basic knowledge of AI. However, despite one of them having received some AI training in the past, all three indicated that they lacked the confidence to teach it due to inadequate professional training.

Moreover, in the diamond ranking activity, the focus group placed the following three cards at the top of the diamond formation, indicating they deemed these critical for effectively teaching AI literacy to young students: (a) "*I can design and teach lessons that appropriately combine AI, technologies, and teaching approaches*" (TPACK knowledge); (b) "*I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn about AI*" (also TPACK); and (c) "*I know how to use AI educational tools*" (TCK). This focus group stated that:

> *The foundation of effective AI implementation in education primarily rests on our [teachers] solid content knowledge about AI [TCK, TPACK]. Tools and pedagogical methods are indeed useful, but without solid content knowledge, teaching cannot occur effectively. Our current priority is to deepen our content knowledge of AI to ensure that we can teach it with proficiency*.

While these three teachers agreed that tools and pedagogical methods are valuable, they also indicated that tools and pedagogies should serve to support the teaching of core AI concepts rather than being the focal point themselves. In addition, all three teachers were unsure about what needed to be added to their existing curriculum.

7.4 | RQ4: What factors influence teachers' attitudes toward the use of AI educational learning tools in AI literacy education for young students?

The qualitative and quantitative analyses revealed that there are various factors influencing teachers' attitudes toward the use of AI educational learning tools in AI literacy education.

7.4.1 | Qualitative analysis

Based on the responses of 21 teachers who responded to the second survey (with three open questions), the major three factors that influence teachers' attitudes toward the adoption of AI learning tools in AI literacy education are insufficient CK and experience with AI [TCK] ($n = 13$), personal struggle for improvement in AI and technical knowledge for classroom integration ($n = 12$), and concerns regarding the risks and benefits of AI educational tools ($n = 5$). The representative examples of teachers' responses are presented in Table 3.

Insufficient CK and experience with AI (i.e TCK) was commonly reported ($n = 13$). The following quotations illustrate that teachers perceived their AI literacy knowledge and AI technological skills as insufficient.

> "*Our teachers don't know AI. First, we need to master AI literacy knowledge before we can teach students*." (Teacher 14)

TABLE 3 Factors influence teachers' attitudes toward artificial intelligence (AI) educational tools.

Factors	*N* =	Samples
Insufficient content knowledge and experience with AI [TCK]	*N* = 13	"*Our teachers don't know AI, first, we need to master AI literacy knowledge before we can teach students* (Teacher 14)". "*I am not familiar with AI, I never used these AI tools in the past* (Teacher 15)". "*Teachers don't know how to use AI tools and we don't have an AI educational background* (Teacher 24)".
Personal struggle for improvement in AI and technical knowledge for classroom integration	*N* = 12	"*Mastery of AI knowledge and skills is a time-intensive process, requiring a significant investment of time* (Teacher 13). "*Offering AI training to teachers is essential* (Teacher 10)". *Given the advanced nature of AI, I lack the requisite technological and computer knowledge to deal with technical issues in the classroom* (Teacher 17)."
Concerns regarding the risks and benefits of AI educational tools	*N* = 5	"*AI tools are not inherently human-centered and may lack flexibility in aligning with our curriculum* (Teacher 7)". "*When using AI tools like ChatGPT in AI classroom instruction, there is a potential risk of students copying from ChatGPT, leading to possible instances of plagiarism* (Teacher 15)". "*I am particularly concerned about the prolonged use of AI and computers as the primary tools for the AI curriculum, as this may affect the cognitive development and visual health of young students* (Teacher 11)." "*AI educational tools will affect children's health* (Teacher 24)".

> "*I am not familiar with AI (in teaching); I've never used these AI tools in the past (for teaching).*" (Teacher 15)
> "*Teachers don't know how to use AI tools (in their classroom) and we don't have an AI educational background*." (Teacher 24)

Personal struggle for improvement in AI and technical knowledge for classroom integration ($n = 12$) was also frequently reported. Several teachers indicate that they continuously struggle to improve their AI literacy and skills. According to one teacher, "*Mastery of AI knowledge and skills is a time-intensive process, requiring a significant investment of time*" (Teacher 13). Some teachers expressed that:

> "*Offering AI training to teachers is essential.*" (Teacher 10, 11,12)
> "*Given the advanced nature of AI, I lack the requisite technological and computer knowledge to deal with technical issues in the classroom.*" (Teacher 17)

Concerns regarding the risks and benefits of AI educational tools ($n = 5$) Teachers considered the benefits and drawbacks of using AI educational tools with students. For example, one teacher stated that:

> "*When using AI tools like ChatGPT in AI classroom instruction, there is a potential risk of students copying from ChatGPT, leading to possible instances of plagiarism.*" (Teacher 15)

Another teacher stated that "*AI tools are not inherently human-centered and may lack flexibility in aligning with our curriculum*" (Teacher 7).

Teachers also expressed concern that prolonged human interaction with AI and computers could be harmful to students. According to one teacher,

"The use of AI educational tools excessively will make students overly dependent on technology for learning." (Teacher 7)

Regarding the potential drawbacks of the frequent use of AI and computers, one teacher stated that:

"*I am particularly concerned about the prolonged use of AI and computers as the primary tools for the AI curriculum, as this may affect the cognitive development and visual health of young students*" (Teacher 11)

7.4.2 | Quantitative analysis

On the other hand, the quantitative findings reveal that there are five factors influencing teachers' attitudes toward the adoption of AI educational tools in AI literacy education: (a) self-perception of AI knowledge and experience in teaching AI literacy (TCK); (b) technical challenges and stakeholder acceptance; (c) the attributes of AI educational learning tools; (d) school infrastructure and budget constraints; and (e) potential for distraction and negative emotional responses (see Table 4).

TABLE 4 The descriptive statistics detailing teachers' attitudes toward the use and integration of artificial intelligence (AI) educational tools.

			95% confidence interval	
Theme	**Survey item**	**Mean (S.D)**	**Lower**	**Upper**
Teachers' perception of their AI content knowledge and experience in teaching AI literacy (i.e.TCK)	Q30. Lack of teachers' knowledge and information about how to use and operate	4.03 (0.446)	3.88	4.18
	Q31. Is too advanced and highly complex. I do not have experience in using these tools and lack of training opportunities	4.00 (0.478)	3.84	4.16
Technical challenges and stakeholder acceptance.	Q23. Technical issues with AI educational tools such as social robot limitations and malfunction	4.00 (0.414)	3.86	4.14
	Q26. Limited acceptance and resistance from parents and other stakeholders about the use of AI learning tools in the classroom	3.58 (0.906)	3.28	3.89
Attributes of AI educational learning tools	Q29. Have safety issues and a physical threat to students	3.89 (0.622)	3.68	4.1
	Q25. Each AI tool has its limitations as a learning aid and may not facilitate the teaching of the curriculum	3.86 (0.639)	3.64	4.08
School infrastructure and budget constraints	Q22. Classroom space is small and not enough for the movement and storage of AI educational tools such as social robots	3.86 (0.798)	3.59	4.13
	Q24. The cost of AI educational tools such as social robots is high	3.67 (0.926)	3.35	3.98
Potential for distraction and negative emotion responses	Q28. Distract students from learning	3.72 (0.741)	3.47	3.97
	Q27. Elicits negative emotions, reactions, and behaviors from students	3.69 (0.749)	3.44	3.95

Note: Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

Teachers' perceptions of their AI CK and experience in teaching AI literacy (TCK)
Teachers acknowledged their limited knowledge with AI, as evidenced by their self-perceived lack of understanding of operating AI educational tools (Q30 mean = 4.03, s.d.0.446) and their limited experience in using them for teaching AI literacy (Q31 mean = 4.0, s.d.0.478).

Technical challenges and stakeholder acceptance
Teachers reported concerns about technical challenges (Q23 mean = 4.0, s.d.0.414), as well as limited acceptance by stakeholders (i.e., teachers and parents) (Q26 mean = 3.58, s.d.0.906).

The attributes of AI educational learning tools
The attributes of AI educational tools, including safety concerns and potential physical threats to young students (Q29 mean = 3.89, s.d.0.622), along with the realization that each AI tool has its limitations as a learning aid (Q25 mean = 3.86, s.d.0.639), were also noted.

School infrastructure and budget constraints
The suitability of school infrastructure was identified as a potential barrier, with concerns raised about limited classroom space for AI tool movement and storage (Q22 mean = 3.86, s.d.0.789), and school budgets regarding the costs associated with acquiring AI educational tools (Q24 mean = 3.67, s.d.0.926).

Potential for distraction and negative emotional responses
The potential for distraction and negative emotional responses among students due to AI-human interaction was recognized (Q27 mean = 3.69, s.d.0.749), with concerns about the impact of such distraction and responses on learning outcomes (Q28 mean = 3.72, s.d.0.741).

7.5 | RQ5: What types of support do teachers perceive as necessary to enhance the implementation of AI educational learning tools in AI literacy education?

Emerging from the qualitative data from the open questions in the second survey (Table 5), teachers cited professional development to overcome individual-level barriers ($n = 15$) and policy support such as additional funding to overcome systemic barriers ($n = 7$) as necessary to facilitate the use of AI learning tools in AI literacy education.

First, professional development and training were repeatedly identified by respondents as being able to enhance their own AI literacy knowledge and pedagogical skills for teaching AI literacy. The findings are well-reflected in the following statements from teachers:

TABLE 5 Qualitative data from teachers' perceived supports.

Perceived support	*N* =	Samples
Professional development to overcome individual-level	*N* = 15	"*Pre-service AI literacy training is a necessity.*" (Teacher 7) "*Professional development is required.…I have concerns about the implementation of AI literacy because teachers may not be able to manage how to use these AI educational tools.*" (Teacher 14) "*Training is required…Teachers not only need AI technological knowledge but also how to teach AI literacy because students are so young.*" (Teacher 22)
Policy support to overcome systemic barriers	*N* = 7	"*Time constraints are a significant factor…We need additional funding.*" (Teacher 13) "*Policy support will help.*" (Teacher 21) "*Training and policy support.*" (Teacher 24)

> "*I have concerns about the implementation of AI literacy because teachers may not be able to manage how to use these AI educational tools."* (Teacher 14)
> "*Teachers not only need AI technological knowledge but they also need to know how to teach AI literacy because students are so young."* (Teacher 22)
> "*There is no support for the teachers at the moment."* (Teacher 9)

While many teachers advocate in-service professional development, one teacher emphasized that "*Pre-service AI literacy training is a necessity*" (Teacher 7). Another teacher stated that "*Training is also critical*" (Teacher 10).

Second, teachers believed that there is a need for policy support to overcome systemic barriers ($n = 7$). Some teachers suggested "*additional* funding" ($n = 3$).

In relation to systemic barriers, the respondents also highlighted the importance of allocating additional time and financial resources to teachers and schools to facilitate the use of AI educational tools. For example,

> "*Time constraints are a significant factor.*" (Teacher 13, 19)
> "*Mastering AI literacy knowledge for teaching students requires considerable time investment* (Teacher 13)" and "*Workload will be increased.*" (Teacher 12)

Another two teachers also stated that

> "*We need the updated and new hardware and resources*." (Teacher 11) and "We n*eed more money.*" (Teacher 13)

8 | DISCUSSION

Based on the TAM model and the TPACK framework, this study offers several key insights into teachers' attitudes and perceptions regarding AI literacy education for young students as well as their acceptance of AI educational tools, comparing these findings with existing literature to contextualize and understand their broader implications. The study reveals that teachers reported insufficient AI CK and experience in teaching AI literacy (TCK), and a lack of familiarity with TPACK knowledge. However, they expressed positive attitudes regarding the use of AI educational tools for teaching AI literacy to young students. Moreover, teachers reported that professional development and funding support will be able to ease teachers' individual and systemic barriers to teaching AI literacy.

First, based on the TAM model, the findings of this study revealed that teachers had positive perceptions about the ease of use and usefulness of AI educational tools in AI literacy education for young students. This finding aligns with systematic reviews by Crompton et al. (2024) and Yim and Su (2024), which highlight the effectiveness of AI tools in enhancing students' AI knowledge and skills. Similarly, the majority of teachers in this study expressed a positive attitude toward teaching AI literacy to young students, echoing Polak et al. (2022), who find a high willingness among teachers in Bulgaria, Greece, Italy, and Romania to introduce AI-related content to students.

Second, in line with Chiu et al. (2023), who examine AI teaching in universities, the study finds that teachers possessed insufficient technological knowledge (i.e., TCK), as well as a lack of CK regarding AI literacy. Another shared similarity was the prevalence of low self-confidence among teachers regarding AI educational tools, which stems from inadequate access to relevant TPACK knowledge, as noted by Su et al. (2022). Also consistent with prior studies (Vartiainen et al., 2020; Williams et al., 2021), the teachers in this study typically had limited prior experience with the use of AI educational tools and teaching AI literacy to young students.

Third, this study identifies five factors that influence teachers' attitudes toward the acceptance of AI educational tools in AI literacy education: (a) their perceptions of their AI CK and experience in teaching AI literacy (TCK); (b) technical challenges and stakeholder acceptance; (c) the attributes of AI educational learning tools; (d) school infrastructure and budget constraints; and (e) potential for distraction and negative emotional responses.

While the teachers in this study generally endorsed AI educational tools individually and supported AI literacy education, these positive attitudes were not commonly translated into practical implementation. The factors that influence teachers' attitudes toward the use of AI educational learning tools in AI literacy education for young students are likely tied to the teachers' understanding and definition of AI. This diverse conceptualization of AI among the teacher respondents could vary greatly between individuals, leading to a wide range of perspectives on the potential benefits and drawbacks of using AI educational learning tools in the classroom. This study also reveals that teachers potentially lack the confidence to use AI educational tools and that they require more information on evaluating and effectively integrating these tools with content in the primary school classroom. While individual acceptance of AI is important, it does not necessarily render AI literacy education for young students sustainable or effective. The study highlights the need for collective efforts and comprehensive training for the entire teaching team to ensure a consistent and sustainable approach to teaching AI literacy to young students.

Despite previous studies and reviews agreeing on the effectiveness of AI educational tools in AI literacy education for young students (Yim & Su, 2024), teachers in this study have expressed concerns about these tools. This finding corresponds with Wegerif and Major (2023), who note that educational technology often provokes controversy among teachers, particularly when perceived as a distraction undermining students' learning agency (Han et al., 2024). Moreover, this study reveals additional concerns from teachers about the potential negative impacts of educational technology on young students' cognitive development and visual health. This finding highlights the importance of collaboration with Information Technology (IT) companies and research institutions to support educators' needs and address risk concerns when designing and integrating AI educational tools into teaching practices (Luckin et al., 2022). Teachers must be informed by IT companies of the limitations and risks associated with their educational tools.

Teachers' lack of knowledge of readily available educational tools and age-appropriate teaching materials for teaching AI to young students requires that they undergo ongoing training in order to remain updated in emerging AI educational settings (Su et al., 2022). This study corroborates research by Sperling et al. (2024) and Marques et al. (2020) highlighting the scarcity of professional development for teachers in AI literacy education. The results of this study also align with the review of Crompton et al. (2024), who find that without knowing how to effectively implement AI in teaching and learning, educators will likely use AI tools ineffectively or not at all. This study indicates that teachers perceive ongoing training, technical support and funding as able to increase teachers' motivation to use AI educational tools within the context of the Chinese educational system.

Lastly, some teachers suggested that, while they would be keen to use more AI educational learning tools in their classes, they are concerned that they would be restricted by constraints related to school budget and infrastructure, such as limited storage space and the cost of AI educational tools. The teachers also expressed concerns that such tools may limit their pedagogical scope, produce negative emotional responses from students, and cause distraction and potential visual health problems in the classroom. As a result, teachers suggested that they may prefer an approach based more on the arts and less on technology. This study contributes to the existing literature by suggesting that teachers tend to opt for an arts-based approach to teaching AI literacy. This could be due to teachers' belief that such an approach involves more direct human interaction and that it could balance the use of AI tools with other non-technological pedagogies in order to ensure students' well-being and diverse learning experiences. This readiness by teachers to integrate AI tools with arts-based methods can create opportunities for a more adaptive alternative to traditional AI literacy education.

9 | RESEARCH IMPLICATIONS

9.1 | Theoretical implications

This study contributes to the existing literature by arguing that the TAM model and the TPACK framework are valuable for understanding teachers' perceptions of the ease of use and usefulness of AI educational tools, as well as their level of TPACK in relation to AI literacy education for young students. By focusing on factors such as the ease of use and usefulness of AI educational tools, as well as teachers' perspectives on AI literacy, this paper sheds light on the factors that influence teachers' acceptance of AI educational tools for AI literacy teaching. In doing so, the study highlights the significance of the TAM and TPACK in facilitating the adoption of AI educational tools in educational settings aimed at young students.

9.2 | Pedagogical implications

The results of this study indicate that while teachers recognize the value and acceptability of AI educational tools in AI literacy education, there is a notable interest among educators in incorporating an arts-based approach to enrich the learning experiences of young students. In the context of AI literacy education, this approach, as described by Yim (2023), aims to empower students to think creatively while building their conceptual understanding of AI. Furthermore, the arts-based approach aligns with the growing emphasis on holistic and interdisciplinary approaches, catering to the diverse learning styles and interests of young students (Su et al., 2024; Tan, et al., 2020; Yim, 2024b).

10 | RECOMMENDATIONS

10.1 | Researchers

Based on this study, researchers are encouraged to explore teachers' competence in AI literacy with a particular focus on knowledge of TPACK and TCK for professional development. In addition, they could also critically evaluate the effectiveness of AI educational tools and share evidence-based findings on their risks and possibilities with policymakers and educators for informed decision-making.

10.2 | Policymakers

Policymakers are recommended to develop proactive strategies and regulations to ensure the safe and positive use of AI educational tools in schools. It is also advised to allocate more resources and funding for professional development to empower both in-service and pre-service teachers, provide up-to-date AI educational tools in AI literacy education, as well as establish ongoing technical support mechanisms. To support teachers in effectively using AI educational tools, detailed technical guidelines should be provided. These guidelines should cover the capabilities and limitations of the tools, their usability and accessibility, potential risks and unintended consequences, as well as evidence-based instructional practices for their integration. This could enhance teachers' motivation to access and incorporate these AI educational tools into AI literacy education. Additionally, the government could foster research collaboration with the AI industry to drive innovation, while policymakers could also facilitate partnerships between schools and AI developers to ensure the accessibility of advanced AI educational tools and technologies for schools.

10.3 | Educators

Educators, as the key stakeholders in AI literacy education, are encouraged to access professional development opportunities and advocate for equitable access to AI educational tools and resources to effectively teach AI literacy in a safe and inclusive technological environment. Further collaboration is needed to facilitate discussions between developers, designers of AI educational tools, and school teachers. This collaboration should aim to better understand teachers' needs, concerns, and teaching goals, ensuring the design of AI educational tools that are relevant, effective, and aligned with school curricula.

11 | LIMITATIONS AND FUTURE DIRECTIONS

This study has employed a mixed method to triangulate its results. The discrepancy between survey responses and focus group findings suggests limitations in using surveys within the context of this exploratory study. The differences in their responses may be a reflection of the wide diversity in how teachers conceptualize and think about AI. Due to the design of the surveys, they may not have accurately captured the full extent of teachers' knowledge and understanding. The focus group provided a more in-depth understanding of teachers' perceptions, AI literacy knowledge, and professional development needs. This perhaps highlights the need for more comprehensive assessment tools, such as detailed questionnaires, interviews, or interactive workshops, to better gauge teachers' familiarity and perspectives regarding AI literacy.

User acceptance of technology is fundamental to the effective uptake of technologies (Davis, 1989). However, this study only considers the perspective of teachers. Future studies should also consider other key stakeholders, such as the perceptions of students and their parents in terms of their acceptance of using AI technological tools in AI literacy education. This paper calls for researchers to investigate the perceptions of students and their parents regarding AI literacy education, as well as to design professional development program for in-service and pre-service teachers that are tailored to their local contexts.

Understanding different stakeholders' perceptions of AI educational tools can help identify better ways to invest resources in AI literacy education for young students. AI educational technologies for young students include hardware-focused and software-focused tools, and intelligent agents (Yim & Su, 2024); however, this study employs the broad term "AI educational tools". As such, future research may define such tools more specifically in order that policy-makers know which tools should be supported and funded.

From a research perspective, this study provides an opportunity for researchers to further explore the acceptance of AI educational tools in AI literacy education for young students, examining viewpoints beyond those covered in this study. Future research could investigate additional dimensions, including how cultural factors influence the acceptance of AI educational tools among teachers and students, and evaluate the effectiveness of arts-based approaches in AI literacy education for young students. By broadening the scope of inquiry, researchers may enhance their understanding of AI educational tools in AI literacy education, thereby contributing to the development of informed pedagogical practices and policies.

12 | CONCLUSION

To effectively implement AI literacy education using AI educational learning tools for young students, it is important to understand teachers' perceptions and acceptance of technologies, their perceived support, and their professional development requirements. Teachers are more likely to embrace AI educational learning tools if they find them beneficial for enhancing student learning outcomes. This

study identifies that teachers perceive their TPACK and TCK knowledge as insufficient. It provides insights for policymakers to strategize professional development initiatives, addressing the needs of both in-service and pre-service teachers, allocating sufficient funding, and establishing ongoing technical support mechanisms. This approach ensures that teachers acquire the necessary skills and knowledge to effectively use AI educational tools in the classroom. Moreover, this study contributes to the literature by indicating that teachers are supportive of exploring new pedagogical methods for AI literacy education through integrating AI educational tools with an arts-based approach.

AUTHOR CONTRIBUTIONS

Iris Heung Yue Yim: Conceptualization; Data curation; Formal analysis; Methodology; Validation; Visualization; Writing - original draft. **Rupert Wegerif**: Supervision; Validation; Writing - review & editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article.

ETHICS STATEMENT

Research approval was obtained from the Research Ethics Committee in the authors' institution. This work was supported by the University o Cambridge under Wolfson College Travel and Research Grants Year 2024 (Reference TA23091). Informed consent was obtained from all participants. They were informed that participation was voluntary and that they could withdraw from the study at any time and for any reason. There are no potential conflicts of interest in this study. The data supporting the findings have not been made publicly available; however, tables, figures, and surveys can be found in various locations: Figures 1–4 and Tables 1–5, with excerpts provided in Appendices A, B, and C.

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APPENDIX A

Survey 1 with 27 rating questions (adapted and modified from Khanlari, 2016).

Survey 1
1. Consent to participate in this survey
Demographic information
2. Gender
3. Age
4. Educational qualification
5. Teaching experience (years)

(Continues)

(Continued)

Survey 1
6. Have you ever attended AI literacy teacher professional training?
Perception of ease of use
9. Easy and convenient to facilitate teaching
Perception of usefulness
8. Reduces teacher workload
10. Enhance students' class participation and engagement
11. Is an alternative tool to enhance students' learning
12. Develops communication, language and social skills
13. Develops cognitive thinking, skills, and abilities
14. Save teaching time
15. Allow teachers to spend more time on students and their learning
16. Promotes and helps students to develop appropriate behaviors
17. Promote creativity of students
18. Enhance students' AI knowledge
19. Promote students about how to use and interact with AI and develop their AI skills
20. Correct students' any misconception about AI
21. Construct new knowledge with AI
Attitudes of teachers
About school infrastructure
22. Classroom space is small and not enough for the movement and storage of AI educational tools such as social robots
24. The cost of AI educational tools such as social robots is high.
About technical challenges and stakeholder acceptance.
23. Technical issues with AI educational tools such as social robot limitations and malfunction
26. Limited acceptance and resistance from parents and other stakeholders about the use of AI learning tools in the classroom
About attributes of AI educational tools
25. AI educational tools have their limitations as learning aid and may not be facilitate the teaching of curriculum
29. Have safety issue and a physical threat to students
About human and AI interactions
27. Elicits negative emotions, reactions and behaviors from students
28. Distract students from learning
About teachers' technological knowledge
30. Lack of teachers' knowledge and information about how to use and operate
31. AI educational tools are too advanced and highly complex. I do not have experience in using these tools and lack of training opportunities

(Continued)

Survey 1
About pedagogical strategies
34. Do you agree it is necessary to teach students AI literacy
32. Do you agree on the need to use the arts to teach students AI literacy
33. Do you agree on the need to use AI educational learning tools such as social robots to teach students AI
About content (open question)
7. From your understanding, describe what you think artificial intelligence (AI) literacy means to you
35. What do you wish to be added to your current curriculum/program regarding AI literacy learning and teaching?
Others (open question)
36. Any other comments you would like to share?
37. If you would like to be invited for a focus group discussion or interview, kindly leave your name, email address and/contact number. Thanks

Note: Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

APPENDIX B

Twelve statements for diamond ranking activity (adapted and modified from Kong et al., 2023).

Statements for diamond ranking activity in AI literacy education
Content knowledge (CK)
1) I have sufficient knowledge of AI.
2) I can think computationally.
3) I have various ways and strategies for developing my understanding of AI.
Pedagogical content knowledge (PCK)
4) Without using technology/computer, I know how to select effective teaching approaches to guide students in thinking about and learning AI.
5) Without using technology/computer, I can help my students to understand AI content in various ways.
6) Without using technology/computer, I can introduce the content of AI to my students.
Technological pedagogical content knowledge (TPACK)
7) I can design and teach lessons that appropriately combine AI, technologies, and teaching approaches.
8) I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn about artificial intelligence.
9) I can provide support and leadership in helping others to coordinate the use of coding, programming, technologies, and teaching approaches at my school and/or district.
Technological content knowledge (TCK)
10) I know how to use Teachable Machine for AI literacy education AI. (e.g. Scratch for programming intelligence projects, ChaptGPT for generating text-based response, "Quick, Draw!" for learning about AI, Google Teachable Machine for creating machine learning models)
11) I can explain the advantages, disadvantages, and limitations (such as data bias and justice) of using Teachable Machine in artificial intelligence education.

(Continues)

(Continued)

Statements for diamond ranking activity in AI literacy education
12) I can choose appropriate images and use tools to train and build AI datasets, such as those availble in Teachable Machine.

APPENDIX C

Survey 2 with three open questions.

Survey 2
1. Consent to participate in this survey
Demographic information
2. Gender
3. Age
4. Educational qualification
5. Teaching experience (years)
6. Have you ever attended AI literacy teacher professional training?
Open questions
Q1: What you do think about the AI literacy education implementation in Hong Kong? Any difficulties and challenges?
Q2: What supports do you feel is needed to help you implement/introduce AI learning in educational settings?
Q3: What would you be most worried about if an AI learning program were implemented for young students in Hong Kong?