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Artificial Intelligence literacy training for rural primary and secondary school teachers from the perspective of complex dynamic systems theory: What do teachers really need?

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Abstract

The rapid development of artificial intelligence (AI), particularly generative AI, has created an urgent need to strengthen rural primary and secondary school teachers' AI literacy. However, existing professional development often emphasizes isolated tools or short-term training and provides limited evidence about rural teachers' authentic learning conditions, technology acceptance, and preferred forms of support. Guided by Complex Dynamic Systems Theory (CDST) and the Unified Theory of Acceptance and Use of Technology (UTAUT), this mixed-methods study investigated the current status, attitudes, barriers, and learning needs of in-service rural primary and secondary school teachers in China. Questionnaire data were collected from 101 rural teachers and complemented by semi-structured interviews with teachers and AI education experts. The findings indicate that rural teachers generally demonstrate strong intrinsic motivation, positive learning attitudes, and confidence in learning and applying AI. They also perceive substantial performance benefits and report supportive social influences. Nevertheless, their learning remains fragmented and informal, and the translation of AI knowledge into routine pedagogical practice is constrained by insufficient systematic training, limited time, inadequate subject-specific resources and technical support, concerns about the reliability of AI-generated content, and regional disparities. Rural teachers expressed the strongest demand for practical support in AI-assisted resource development, instructional design, teaching management, learning analytics, and professional development, delivered through concise videos, cases, tool links, downloadable resources, and sustained interactive support. The study conceptualizes rural teacher AI literacy as a context-dependent and dynamically developing competence and argues for systematic, flexible, differentiated, and practice-oriented professional learning environments that connect technological knowledge with authentic teaching tasks.

Introduction

AI is becoming increasingly embedded in educational practice. UNESCO released AI competency framework for teachers (UNESCO 2026). The emergence of generative AI has further expanded its potential applications in lesson preparation,

resource development, classroom interaction, assessment, learning analytics, school management, and teachers' professional learning. As AI tools become more accessible to students and teachers, primary and secondary school educators are expected not only to operate these technologies, but also to evaluate their outputs critically, integrate them pedagogically, and address issues related to accuracy, ethics, privacy, equity, and student development (Huang, 2023). Teachers' AI literacy has therefore become an essential component of contemporary professional competence (Ng et al. 2024).

For rural primary and secondary school teachers, AI literacy extends beyond general awareness or technical proficiency. It involves understanding the basic principles and limitations of AI, selecting and using appropriate tools, evaluating AI-generated information, making responsible ethical decisions, and aligning AI use with curriculum goals, learner characteristics, and subject-specific pedagogy (Author & Author, 2026). This broader conception is especially important in K–12 education because rural teachers mediate students' first sustained encounters with AI and influence how younger learners understand, trust, and use intelligent technologies. Weak teacher AI literacy may result in superficial adoption, overreliance on generated content, inappropriate use of student data, or the reproduction of inaccurate and biased information. By contrast, well-developed AI literacy can enable teachers to make informed professional judgments and use AI as a support for, rather than a substitute for, pedagogical expertise (Younis, 2024).

Although interest in teacher AI literacy has grown rapidly, current professional development practices remain uneven. Many training activities are organized as one-off lectures, demonstrations of popular tools, or decontextualized introductions to AI concepts. Such activities may increase awareness, but they do not necessarily help rural teachers integrate AI into daily instruction. Rural teachers differ substantially in subject area, educational level, prior technological experience, school resources, and local policy environments. Their learning time is often fragmented, and the technologies themselves evolve rapidly. Consequently, a standardized and static training model is unlikely to address the diverse and changing conditions under which teachers learn and apply AI (e.g., Ding et al. 2024; Palmquist et al. 2026).

The existing literature also leaves several gaps. First, many studies focus on defining AI literacy, constructing competency frameworks, or examining students and university educators, while the authentic learning conditions and professional needs of in-service K–12 teachers remain comparatively underexplored. Second, studies of technology acceptance often examine behavioral intention without connecting it to the specific content, resource formats, and support mechanisms teachers need for professional learning. Third, research frequently treats AI literacy as a stable set of individual competencies, paying insufficient attention to the interaction among teachers, technologies, school cultures, institutional support, regional resources, and changing teaching demands. These limitations make it difficult to design professional development that is both theoretically coherent and responsive to practice.

Accordingly, this study investigates the current status of AI-related learning among rural primary and secondary school teachers, their acceptance of AI technologies, the difficulties they encounter, and their preferred learning content and resource formats. A mixed-methods design combining questionnaire and interview data was adopted to capture both overall patterns and the contextual reasons underlying those patterns. By grounding the design of AI literacy training in teachers' authentic professional experiences, this study aims to contribute to a more dynamic understanding of teacher AI literacy and provide evidence for the development of systematic, flexible,

differentiated, and sustainable professional learning environments.

Literature review

Complex dynamic systems theory and UTAUT. Complex Dynamic Systems Theory (CDST) is an interdisciplinary framework that seeks to explain the complex, nonlinear, and dynamic behaviors that emerge in both natural and human-made systems (Ushioda, 2015). At its core, CDST posits that the evolution of a system can be understood by examining the interactions among its constituent components and the emergent patterns of behavior arising from these interactions (e.g., Zheng et al. 2020). Drawing on CDST, Christenson (2012) conceptualized learning engagement as a dynamic process whose emergence and development are shaped by temporal and contextual factors. In education, technology-enhanced learning environments are no longer simple sets of tools, but rather an evolving, complex ecosystem composed of technology, learners, content, and teachers (Zheng et al. 2020). Teaching, by continuously analyzing learner data and adjusting instructional content and strategies (Saqr et al. 2025), reflects the interactive and dynamic characteristics of system elements, achieving a precise match between instructional supply and learner needs. The CDST offers many insights for re-examining education, moving from a static to a dynamic perspective; that is, learning outcomes may not be linearly determined by a single factor, but rather the result of the interaction of multiple factors (Hilpert & Marchand, 2018). From control to understanding and guidance, research on education should shift from seeking universally applicable "best practices" to exploring its dynamic formation mechanisms, thereby enabling effective intervention in the people, technology, and content within the system and guiding its evolution (Koopmans, 2020). The complexity, systematic nature, and dynamism of the AI literacy training environment for primary and secondary school teachers highly align with the core concepts emphasized by CDST. This provides strong support for using this theory as the foundation and basis for constructing learning environments. When constructing learning environments, the interactive influences between different factors should be taken into consideration. For example, understanding learners' real needs, providing them with authentic problem situations, allowing them to explore and practice, and providing personalized learning feedback are crucial to maintaining students' autonomy in online learning (e.g., Tadesse & Davidsen, 2020; Tian, 2024).

The Unified Theory of Acceptance and Use of Technology (UTAUT) is widely employed to examine individuals' acceptance and use of emerging technologies. It seeks to predict users' technology acceptance by accounting for a range of influencing factors and individual differences (Venkatesh et al. 2003). The model comprises four core constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions (see Figure 1). Collectively, these factors shape teachers' acceptance of AI technologies, as well as their attitudes and beliefs regarding the integration of AI into teaching and learning. Teachers' acceptance and use of AI therefore constitute a critical component in enabling AI to generate sustained educational benefits. With the rapid development of AI, its adoption has become an increasingly significant challenge, particularly with regard to how teachers understand, accept, and use AI technologies (Author & Author, 2024). UTAUT provides an appropriate theoretical framework for examining users' adoption of AI, especially within educational contexts (Xue et al. 2026). Ke et al. (2025), for example, applied UTAUT to investigate AI adoption among university students. Their findings indicated that AI literacy was an important predictor of behavioral intention to adopt AI, while social influence, performance expectancy, and effort expectancy played

significant mediating roles. In addition to research on students' AI use, UTAUT has also been applied to examine AI adoption among university educators. Nikolic et al. (2024) employed the UTAUT framework to investigate university teachers' adoption of AI. The findings showed that teachers generally held positive attitudes toward the efficiency of AI and its potential to enhance teaching. However, they also expressed considerable concerns regarding students' academic integrity, the accuracy and reliability of AI-generated information, and the potential effects of AI use on students' skill development. Similarly, Andrews et al. (2021) developed a UTAUT-based questionnaire to investigate AI adoption among librarians and found that performance expectancy and attitude toward technology use had significant effects on AI adoption. Notably, Xue et al. (2026) conducted a review of research applying UTAUT to AI adoption in education. The review revealed that most existing studies have focused on AI use in higher education, whereas research situated in K-12 educational contexts remains limited. Because the conditions, responsibilities, and instructional practices associated with AI use among K-12 teachers differ substantially from those in higher education, there is an urgent need for further research on teachers' AI adoption in K-12 settings.

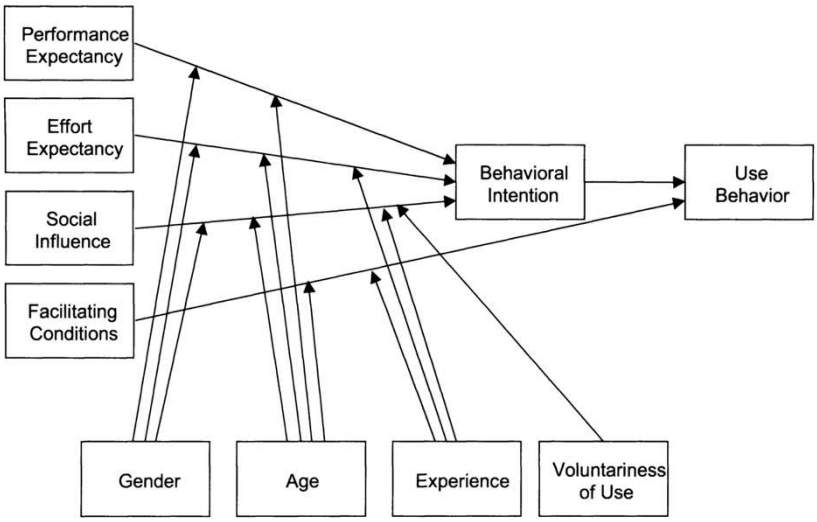


Fig.1. UTAUT model (Venkatesh et al. 2003)

Artificial intelligence literacy. UNESCO's Guidance Report on Generative Artificial Intelligence Education describes AI literacy as a set of skills encompassing three aspects: "learning about AI," "learning how AI works," and "learning to coexist with AI" (Palmquist & Sigurdardottir, 2026). Currently, there is no fully unified consensus in academia regarding the concept and components of AI literacy. It is generally defined broadly as "the set of abilities required for an individual to understand, critically evaluate, and responsibly use AI technologies and to interact effectively with them" (Walter, 2024). Another definition interprets AI literacy as "an individual's ability to understand, evaluate, use, and create AI technologies, including four dimensions: knowledge, skills, attitudes, and ethics" (Shi, 2024). Research has proposed the ABCE framework for AI literacy, a currently popular integrative framework that divides AI literacy into four core dimensions: affect, behavior, cognition, and ethics, emphasizing the importance of the affective dimension (Ng et al. 2024). Other studies have divided AI literacy into knowledge, application, assessment, and ethics (e.g., Wang et al. 2023).

Focusing on AI literacy for primary and secondary school teachers, scholars

understand it as the ability of primary and secondary school teachers to responsibly understand, use, assess, and innovate AI technologies, and on this basis, integrate AI tools with instructional design to promote students' AI awareness and thinking development (Huang, 2023). Representative AI literacy models for primary and secondary school teachers include the Conceptual Framework for Teachers' Digital Intelligence Literacy and the Framework for Professional Competency of Primary and Secondary School AI Teachers (Lintner, 2024).

Research on improving the artificial intelligence literacy of primary and secondary school teachers. Currently, the number of studies on how to improve teachers' AI literacy is constantly increasing, and the academic community is working together to explore effective and efficient methods and pathways. From different perspectives, some studies have explored and proposed possible pathways to improve teachers' AI literacy. At the national level, formulating relevant standards, policies, and development plans, and improving teacher training and evaluation systems (e.g., Younis, 2024). At the school level, consciously building core AI education teams, conducting relevant workshops, and organizing case study observations and discussions to help teachers form a learning community of AI knowledge and build a virtuous cycle from learning, sharing, practice to reflection (e.g., Ding et al. 2024). At the individual level, stimulating teachers' intrinsic motivation for self-directed learning, encouraging them to actively utilize online resources, form learning pairs, and participate in academic exchanges (e.g., Author & Author, 2026).

Therefore, considering the current state of research and cultivation of teachers' AI literacy, to fully leverage the potential effectiveness of learning environments in promoting the construction and development of teachers' AI education and literacy, it is necessary to combine the specific realities of AI education for teachers in local primary and secondary schools, starting from the dimension of AI literacy among local teachers, and designing AI learning resources that are integrated with local teaching needs and scenarios. Based on the preceding discussion and the above analysis, constructing an AI learning environment for primary and secondary school teachers is of significant research importance. Regarding how to construct an effective learning environment and design and develop high-quality AI educational resources, this study raised the following research questions (RQs).

RQ1: What is the current status and competence level of AI education among primary and secondary school teachers?

RQ2: What are the teachers' attitudes towards and learning needs regarding AI education?

Methodology

Instruments. To understand the current status of AI education for teachers in primary and secondary schools, the basic situation of online learning among teachers, assess learners' learning interests and attitudes, and explore the learning needs of primary and secondary school teachers for AI-enabled education, this study conducted a comprehensive survey and analysis through a combination of questionnaires and interviews.

Questionnaire. This study draws on previous researchers' designs of learning environment needs questionnaires, curriculum resource offering surveys, and curriculum resource preference surveys (Andrews et al. 2021; Author et al. 2024; Author et al. 2025) to design a questionnaire on the current status and needs of

primary and secondary school teachers regarding AI-enabled education and learning. The questionnaire consists of five parts: basic information, online learning status, willingness and barriers to using AI technology, current status of AI-enabled education and learning, and online learning environment needs. The questionnaire dimensions are shown in Table 1, and detailed questionnaire questions can be found in Appendix I.

Table 1 Questionnaire topic setting and corresponding dimensions

Dimensions	Section	Question Category	Answer Settings
Basic Information	1	1-2	/
Online Learning Status		3-5	/
Willingness to Accept and Use AI Technology		6-20	Strongly agree/ agree/ neutral/ disagree/ strongly disagree
Current Status of AI Education and Learning		1-4,7,8,9	
Requirements for Online Learning Environment	2	5,6,10	Very much needed/ needed/ average/ Comparison is not required / Absolutely unnecessary

Interview. To address the limitations of questionnaires, this study employed semi-structured interviews to further understand the current state of AI education in schools and the deeper needs of primary and secondary school teachers. The interviews were designed in two versions: one for teachers and one for experts. Based on previous studies related to AI literacy frameworks, the teacher version consisted of 10 questions, covering AI awareness, AI knowledge and skills, AI applications (teaching management and evaluation), and AI-enabled professional development. It also aimed to understand teachers' perspectives on the current average level of AI literacy among the teaching staff, the shortcomings in school AI training, and to solicit suggestions for online learning environments specifically focused on AI. The expert version consisted of 8 questions, primarily focusing on the content, teaching models, resources, and challenges encountered by expert teachers in conducting offline AI education and training in primary and secondary schools. Secondly, it sought to understand the experts' views on the main shortcomings, causes, and improvement paths of primary and secondary school teachers' ability to leverage AI in teaching, explored their suggestions for improving school AI education and training, and solicited constructive opinions on online learning environments. Please see Appendix II for the detailed interview questions. Both questionnaires were administered in Chinese to ensure that participants could accurately understand and respond to all items. English translations of the complete instruments are provided in Appendices I and II.

Participants. Following Institutional Review Board (IRB) approval (Protocol ID: HE693105), all participants signed informed consent prior to data collection. The questionnaire was administered online to in-service rural primary and secondary school teachers across China. A total of 101 questionnaires were collected, resulting in

a 100% response rate. Among the respondents, 81 were secondary school teachers and 20 were primary school teachers; 26 were male and 75 were female, representing various subjects including Chinese, mathematics, English, physics, geography, and information technology. Ten primary and secondary school teachers were randomly interviewed from a range of disciplinary backgrounds, including the humanities, and sciencesive experts in AI education were also invited, and all experts were affiliated with normal universities in China.

Data analysis. For the questionnaire, this study first analyzed its reliability and validity using SPSS Statistics 25. The specific analysis results are shown in Table 2.

Table 2 Reliability and validity analysis of the questionnaire

Project	Contents	Project Value
Cronbach's Alpha	Willingness to Accept and Use AI Technology	.811
	Current status of AI education and learning	.924
	Requirements for Online Learning Environment	.929
KMO	/	.829

The results in this table show that the Cronbach's Alpha coefficients for each dimension of the questionnaire are 0.811, 0.924, and 0.929, respectively, with a KMO value of 0.829, indicating good reliability. Bartlett's test of sphericity reached a significant level ($\chi^2 = 2042.14$, $df = 406$, $p < 0.001$), indicating that the data is suitable for factor analysis. Furthermore, the cumulative variance explained by the first three common factors is 56.54%, demonstrating the ability to effectively measure the target to a certain extent, although further revision and improvement are still needed. The rotated component matrix shows that dimension 2 exhibits a fairly concentrated factor loading (0.655–0.758) on component 1, demonstrating good internal consistency. Dimension 3 also shows ideal convergence on its corresponding components (0.568–0.854). The factor loadings for each item in dimension 1 range from 0.518 to 0.843, reaching an acceptable level. The content validity of the questionnaire was also guaranteed through expert review. Based on the results of the questionnaire, descriptive statistical analysis and one-sample *t*-test were conducted, mainly to provide a detailed presentation of learning styles, current learning status, willingness to use, and needs.

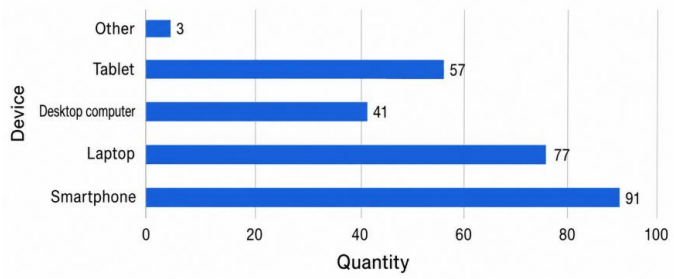
As supplementary material to the quantitative data, the interviews helped us gain a deeper understanding of the reasons underlying the quantitative results. In this study, the findings from the interview data analysis not only complemented the quantitative results but also provided stronger evidence for the study's conclusions through the use of multiple types of data. The interviews were transcribed by the researchers, and two researchers subsequently coded the interview data. Rather than applying a set of predefined categories, they engaged in multiple rounds of close reading and iterative comparison to identify recurring patterns and develop categories grounded in the data (Corbin & Strauss, 2008). After completing the initial coding independently, the researchers met to compare their coding decisions and discuss areas of disagreement. In cases where discrepancies occurred, each coder was required to provide supporting evidence from the interview transcripts and explain the rationale for the proposed code. Any disagreements that remained unresolved were reviewed and adjudicated by

a third researcher.

Findings

To answer RQ 1: What is the current state of AI literacy for primary and secondary school teachers?

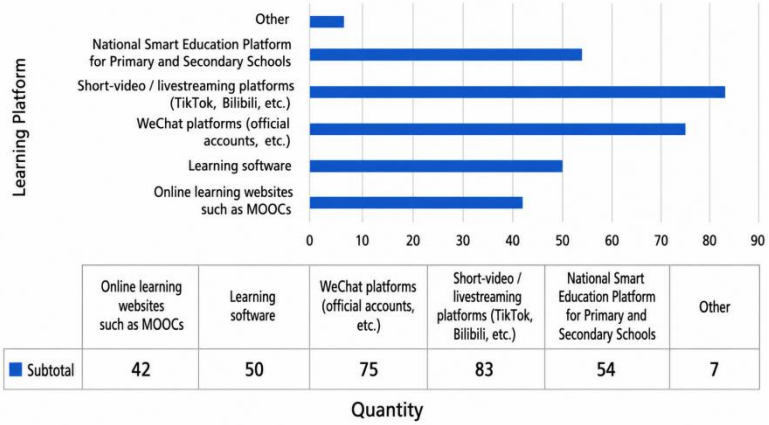
How should primary and secondary school teachers conduct this kind of learning? Based on the questionnaire results, we first examined primary and secondary school teachers' online learning practices in terms of learning duration, learning methods, and devices used. As shown in Figure 2, smartphones were the most commonly used learning device, receiving 91 selections and accounting for 90.1% of the surveyed teachers. Laptops were also frequently used, possibly because of their extensive functionality and portability. One teacher explained, "We now rely more on mobile phones for learning. Teachers often have fragmented periods of time available, so this approach is more convenient" (T01-Q).



	Smartphone	Laptop	Desktop computer	Tablet	Other
Subtotal	91	77	41	57	3

Fig.2 Usage of online learning devices

As shown in Figure 3, over 75% of the total number of people using online learning platforms typically utilize short video or live streaming platforms like TikTok and WeChat official accounts. Secondly, 54% of individuals use the National Smart Education Platform for Primary and Secondary Schools for teaching reference. Among other options, several teachers mentioned Little Red Book social media platform, Baidu Cloud, and Quark Cloud, indicating that these are also important choices among learning platforms. As one teacher noted, "Although the school encourages us to use the national platform, we tend to use TikTok and WeChat more frequently in our daily lives. For me, recommended content and materials shared in group chats are easier to access" (T02-Q).



	Online learning websites such as MOOCs	Learning software	WeChat platforms (official accounts, etc.)	Short-video / livestreaming platforms (TikTok, Bilibili, etc.)	National Smart Education Platform for Primary and Secondary Schools	Other
Subtotal	42	50	75	83	54	7

Fig.3 Usage of online learning platform

In terms of learning duration, as shown in Figure 4, 61 teachers reported spending more than 1 to 2 hours per day on online learning, accounting for 60% of the total respondents. This suggests that online learning has become an integral part of teachers' daily learning practices and serves as an important means for them to acquire knowledge and pursue professional development.

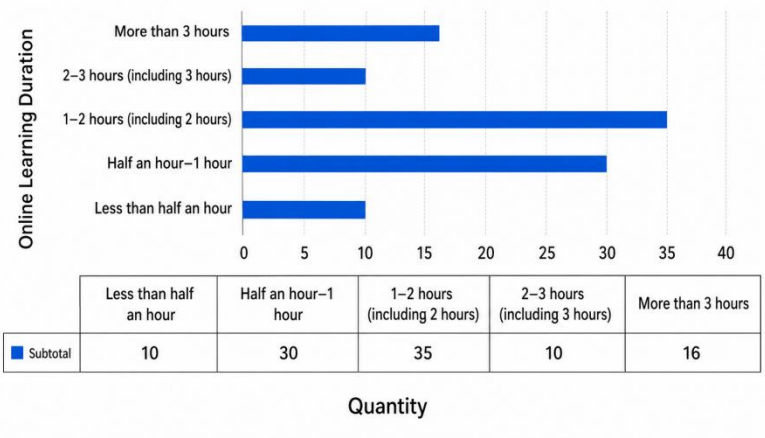


Fig.4 Online learning duration

The current state of primary and secondary school teachers' understanding of AI learning. The section on current learning status primarily analyzes the learning motivation, attitude, self-efficacy, interest, habits, and mastery of AI knowledge among these teachers.

Figure 5 shows that: regarding learning motivation, 88% (no = 89), 86% (no = 87), and 83% (no = 84) of teachers respectively believe that they learn about AI to improve their teaching abilities and efficiency, avoid falling behind in their career development, broaden their knowledge, and enhance themselves. These three motivations are the three main reasons why these teachers learn about AI. Secondly, curiosity about new technologies, personal interest, and a thirst for knowledge are also reasons why they are willing to participate in learning. In addition, fewer than half of the respondents selected externally driven motivations, such as meeting formal requirements for professional title evaluation or career advancement, with the highest proportion reaching only 39%. Overall, the findings suggest that teachers' learning motivation was primarily self-directed and intrinsic. As one teacher explained,

"*AI is developing so rapidly that it would be problematic if my students were using it while I did not understand it. Everyone is using AI now, so I cannot afford to fall behind" (T03-Q). Another teacher similarly noted,"Of course, we pay attention to promotion opportunities, but learning about AI is not directly related to promotion. I simply feel that it is something I should learn*" *(T04-Q).*

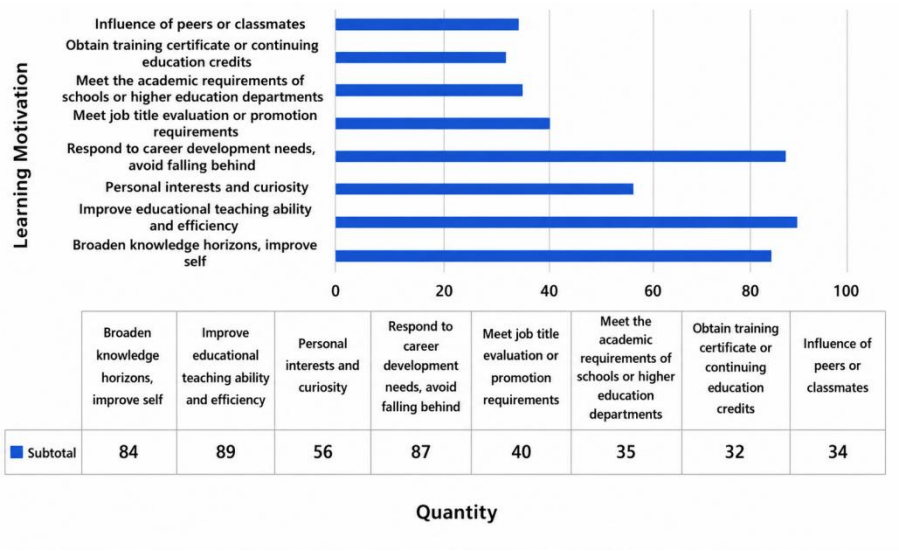


Fig.5 The learning motivation of artificial intelligence education

As shown in Figure 6, regarding learning difficulties, 80% of teachers considered the lack of systematic training and guidance to be the most significant learning challenge, while a lack of time for learning and exploration was also a notable difficulty mentioned by 66% of teachers. This, to some extent, confirms that a current characteristic of learning for primary and secondary school teachers is the fragmentation of their learning time, and offline systematic training is insufficient to effectively resolve this contradiction. This provides a practical basis for the exploration and development of online AI training. As one teacher explained during the interview, “We lack systematic training and structured courses. Most of the time, we only attend occasional expert lectures, and it is also difficult for the school to coordinate a time when all teachers can participate in centralized training sessions” (I01).

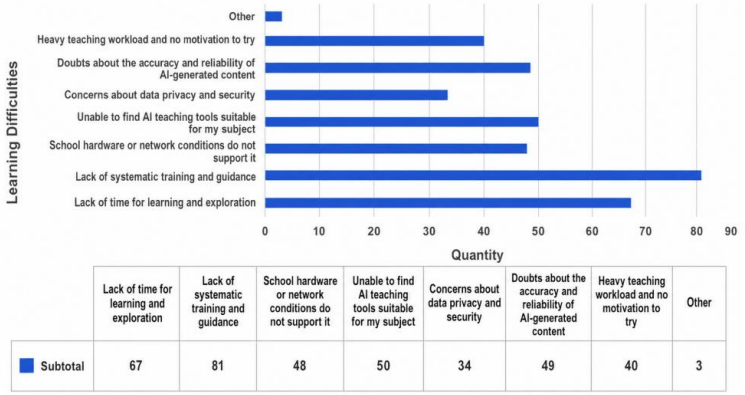


Fig.6 Learning difficulties in AI training

From the perspective of learning attitude, Table 3 shows that 75.25% of teachers have a positive attitude towards their ability to concentrate on training, and 73.27% believe they can actively participate in team teaching research and practice. Furthermore, over 70% of teachers agree or strongly agree that they can diligently study the course videos and complete learning tasks with group members. This indicates that teachers, overall, possess a relatively positive and constructive learning attitude.

Table 3 Analysis of learning attitudes					
Subject	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I am able to concentrate during AI-supported education training and keep pace with expert instructors.	0.99%	0.99%	22.77%	57.43%	17.82%
In AI-supported educational practice, I actively collaborate with team members to engage in teaching research and instructional practice.	0%	0.99%	25.74%	56.44%	16.83%
If I participate in online learning, I can study each course video carefully and attentively.	0%	1.98%	25.74%	53.47%	18.81%
I actively work with group members to complete tasks assigned by instructors.	0%	1.98%	18.81%	61.39%	17.82%

Regarding self-efficacy, Table 4 further shows that 77.32% of teachers agree or higher with their ability to understand and master the basic content of AI; in addition, 70.30% and 73.27% of teachers, respectively, agree or higher with their task completion ability and teaching practice ability. Among them, the highest proportion of teachers, 80.20%, believed that they possessed the ability to actively participate in group collaboration. This finding indicates that teachers possessed a relatively strong sense of self-efficacy in relation to their learning and practical capabilities, providing a solid foundation for their continued engagement in AI-related learning activities. As one teacher explained, “We regularly participate in teaching and research activities and engage actively in them because we believe that learning about these topics is beneficial to our professional development” (I02).

Table 4 Analysis of self-efficacy ability					
Subject	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I believe that I can effectively understand and master basic AI knowledge and skills covered in the training.	0%	2.97%	19.8%	61.39%	15.84%
I believe that I can successfully complete training-related assessment tasks (e.g., reflective reports, instructional design cases).	0%	1.98%	27.72%	57.43%	12.87%
I believe that I can effectively integrate the AI knowledge and skills I have learned into subject teaching.	0%	0.99%	25.74%	55.45%	17.82%
I recognize the importance of teamwork and actively participate in group collaboration with a strong sense of team spirit.	0.99%	1.98%	16.83%	64.36%	15.84%

Regarding learning interest, Table 5 shows that 77.23% and 80.20% of teachers, respectively, held a neutral or higher attitude towards learning AI-related educational content and diverse teaching methods; meanwhile, 81.19% of teachers recognized the importance of learning AI-enabled education knowledge for their own professional development. However, teachers' interest in participating in AI-related teaching competitions was relatively dispersed, with 2.97%, 2.97%, and 26.73% of teachers, respectively, expressing strong disagreement, disagreement, and neutrality. This result also provides a reference for the current institutional design and support mechanism construction of AI-related teaching competitions. As one teacher observed,

"The field is developing rapidly, and these tools are becoming increasingly widespread. Some of the emerging applications are quite engaging, and several of them can provide meaningful support for our teaching" (T06-Q). Another teacher commented, "I am not very familiar with teaching competitions because we have not yet had much exposure to such opportunities. These activities may be more feasible for schools with greater access to resources and funding" (T07-Q).

Table 5 Analysis of learning interests

Subject	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I am very interested in knowledge and skills related to AI-supported education.	0%	0.99%	21.78%	58.42%	18.81%
I believe that learning AI-supported education is important for teachers' professional development.	0%	1.98%	16.83%	57.43%	23.76%
Compared with traditional lecture-based instruction, I prefer experiencing diverse instructional approaches such as case-based learning, practice-based learning, and brainstorming.	0%	0%	19.8%	58.42%	21.78%
I am interested in participating in AI-related teaching practices, such as "AI + Teaching" competitions.	2.97%	2.97%	26.73%	49.5%	17.82%

Regarding learning behaviors, Table 6 shows that 67.33% of teachers proactively arrange pre-class preparation outside of regular coursework, 78.22% are willing to actively seek external help when encountering difficulties, and 73.27% proactively reflect and summarize after class. Furthermore, 65.35% of teachers are willing to actively interact with expert teachers during the learning process. Overall, teachers have initially developed relatively positive online learning habits, but there is still room for improvement in areas such as continuous pre-class preparation, in-depth interaction, and the construction of learning communities.

Table 6 Analysis of learning behaviors					
Subject	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I am able to arrange time for previewing learning materials outside of class.	0%	3.96%	28.71%	54.46%	12.87%
I actively think about questions raised by expert instructors and engage in interactions with them.	0.99%	2.97%	30.69%	50.5%	14.85%
When encountering difficulties, I actively seek help from experts, relevant books, or online resources.	0%	1.98%	19.8%	63.37%	14.85%
After class, I reflect on and summarize what I have learned.	0%	0%	26.73%	54.46%	18.81%

Combining Figures 7 and 8, which illustrate teachers' knowledge of AI and its application in teaching, it's evident that over 90% of the teachers indicated they understand some or most of the relevant AI technologies. Furthermore, 64.35% of the teachers have already applied AI technologies to varying degrees in their teaching. This demonstrates that, in the context of the AI era, teachers generally possess an awareness of proactively engaging with and understanding AI, and have developed a certain level of technical understanding. However, a gap remains between knowledge acquisition and practical application in teaching, indicating that teachers still face a significant "knowledge-practice divide" in transforming AI-related theoretical knowledge into routine teaching practice.

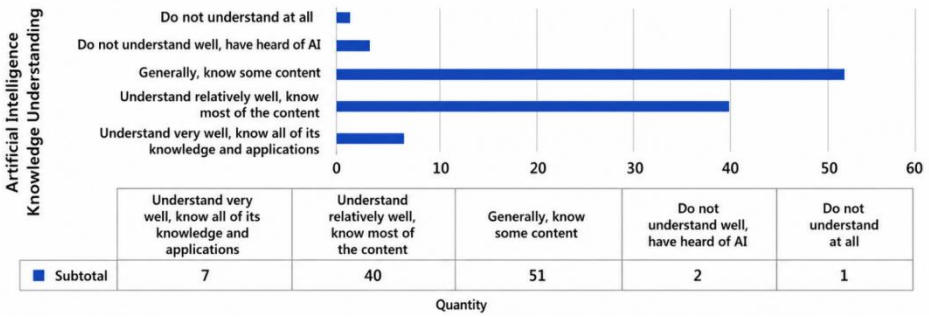


Fig.7 Awareness of artificial intelligence

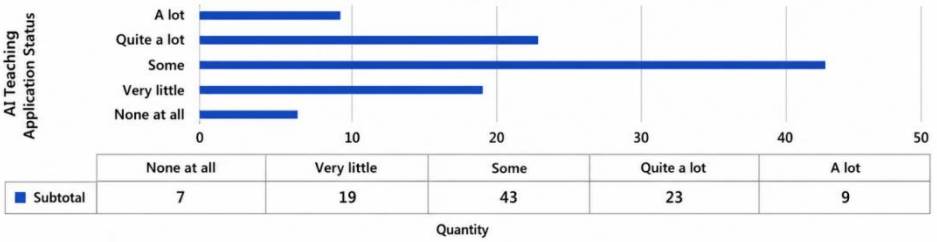


Fig.8 Learning difficulties in artificial intelligence education

To answer RQ 2: Teachers' willingness to accept and use the technology and their learning needs. *Willingness to use.* Items 8 through 20 of the questionnaires were designed based on the UTAUT model to understand teachers' willingness and

obstacles to integrating AI technology into education. Using the theoretical median of 3 on the Likert five-point scale as the criterion, a one-sample *t*-test was conducted on the scores of the four dimensions. The results are shown in Figure 9 and Table 7. Primary and secondary school teachers scored significantly higher than the corresponding theoretical neutral values ($p<0.001$) on all four dimensions: performance expectation (M=8.18, SD=1.252), effort expectation (M=11.48, SD=1.978), social impact (M=15.75, SD=2.147), and convenience conditions (M=14.85, SD=2.582). This indicates that teachers' overall attitude towards learning AI in education and their attitude towards potential obstacles tend to be positive.

Specifically, the survey results were analyzed across four dimensions: performance expectancy, effort expectancy, social influence, and facilitating conditions. Regarding performance expectancy, more than 77% of the teachers agreed or strongly agreed that the use of AI in teaching could enhance classroom efficiency, while more than 87% agreed or strongly agreed that AI could improve their work efficiency. As one teacher explained, "AI can improve both my classroom teaching efficiency and my overall work efficiency. Once we become accustomed to using certain applications, they can save us a considerable amount of time, particularly for tasks such as error correction and feedback" (I03).

Regarding effort expectancy, 43.5% of the teachers agreed that the need for repeated trial and adjustment was a major reason why AI tools could be difficult to use, while more than half agreed that integrating AI into classroom teaching was challenging for primary and secondary school teachers. In addition, 71.2% agreed or strongly agreed that learning to use AI required considerable time and effort. As one teacher explained,

"*When I first started using these tools, I had to test and adjust them repeatedly, which took a great deal of time. Before I could actually use them in the classroom, I had already spent a lot of time preparing, and that was a major challenge. Ideally, the tools should already be properly configured so that I can use them directly" (I04).*

With respect to social influence, most teachers believed that students were more receptive than parents to the use of AI in the classroom. At the same time, more than 75% of the teachers agreed or strongly agreed that the integration of AI into classroom teaching was supported by society and school leaders. As one teacher noted, "Initially, we were somewhat uncertain about whether AI should be used in teaching. More recently, however, both the local education bureau and school leaders have expressed strong support for its use, while also emphasizing the importance of using it appropriately and responsibly" (I05).

Finally, with regard to facilitating conditions, 43.56% of the teachers agreed that the lack of timely and effective technical support constituted a major barrier to the use of AI. More than 70% agreed or strongly agreed that they lacked adequate AI-related teaching resources, while approximately 68.3% acknowledged deficiencies in the knowledge and skills required for AI-supported education. In addition, objective constraints, such as regional economic disparities, were identified as a major concern by approximately 67.3% of the teachers. As one teacher explained, "Our school has limited resources, so we do not receive much support. We also cannot afford to pay for training ourselves, and the school does not reimburse these expenses, so we can only learn on our own" (T08-Q).

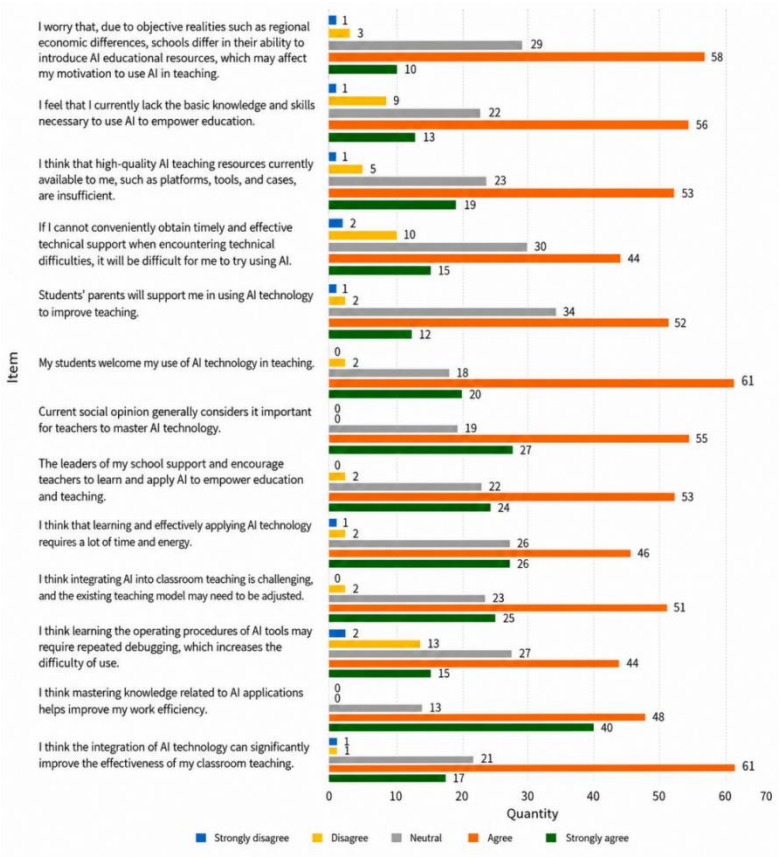


Fig.9 The willingness and obstacles to use artificial intelligence

Table 7 One-sample *T* test				
Dimensions	M	SD	t	p
Performance Expectation	8.18	1.252	17.482	< .001
Effort Expectation	11.48	1.978	12.577	
Social Impact	15.75	2.147	17.568	
Convenience Conditions	14.85	2.582	11.098	

Teachers' usage needs. Regarding the needs of the learning environment, these mainly include teachers' requirements for the content, functions, and formats of resources in the online learning environment. As shown in Figure 10, from the perspective of resource content needs for teaching applications, 93 teachers (92.08% of the total) selected "using AI to efficiently develop teaching resources." For example, one teacher noted, "Preparing teaching materials, such as images, videos, PowerPoint slides, and practice exercises, takes a considerable amount of time. Now, AI can help me with these tasks" (T09-Q). Following this, professional development, AI-assisted teaching management, AI general knowledge, AI-assisted instructional design, and learning analysis were also areas of concern and desire for learning among approximately 80% of teachers. In summary, teachers' learning needs for AI education mainly revolve around two aspects: classroom teaching and personal development.

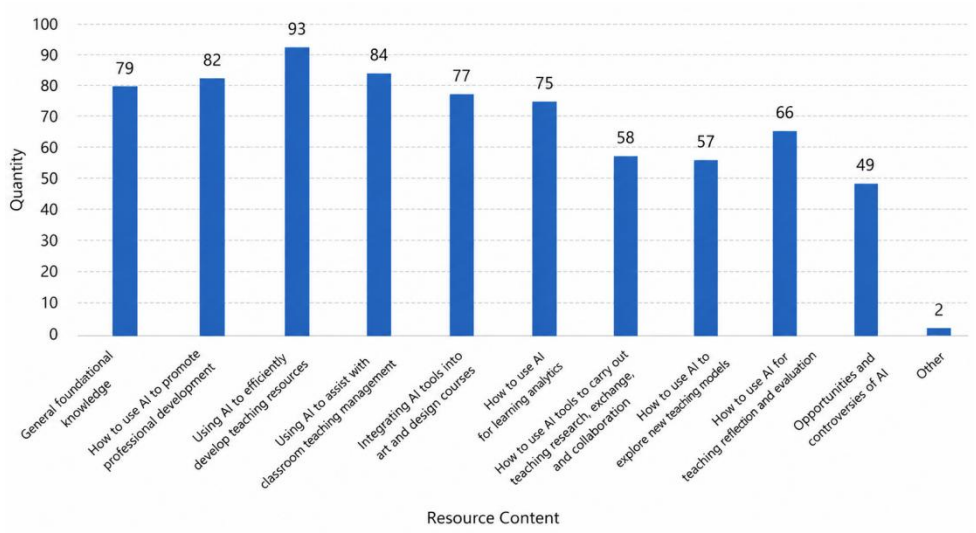


Fig.10 Resource content requirements in teaching application

As shown in Figure 11, from a technical perspective, when ranking different technical knowledge, 70.41% of teachers ranked generative AI-assisted teaching first, possibly indicating that generative AI technology has gained widespread recognition among teachers due to its powerful functions and low barrier to entry. Following this, the order was knowledge graph-assisted personalized teaching, AI assistants for electronic whiteboards, and the combination of XR technology and AI. One teacher noted,

"*The emergence of generative AI has been extremely helpful to me, particularly because it does not require a strong technical background. Of course, we continue to use the functions embedded in interactive whiteboards, as well as the AI tools we used previously*" *(I06).*

Teachers showed relatively less demand for learning about intelligent robots and cloud computing and big data, with 27.27% and 50% of teachers ranking them last, respectively.

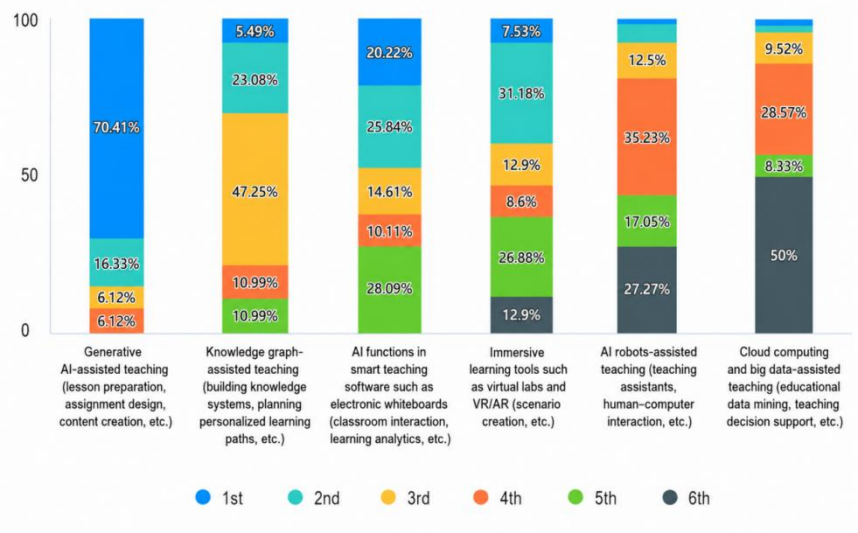


Fig.11 Resource content requirements in technology

From the perspective of function and resource format (as showin in Table 8), the demand for micro-lesson (video) resources, text and image resources, links to related AI tools, and resource download links is the most prominent, with 35.64%, 35.64%,

33.66%, and 39.6% of teachers respectively expressing a strong need for these four resource formats. One teacher noted, “I still need concise and practical instructional resources that can quickly show me how to use these tools, with a greater emphasis on hands-on demonstrations. Ideally, I should be able to understand the process after watching it once” (I07). Information-based resources received the least attention, with only 19.8% of individuals expressing a strong need for them. Furthermore, the demand for interactive, quiz, and assessment functions among primary and secondary school teachers is relatively balanced, with the number of teachers expressing a strong need for each fluctuating around 28% of the total.

Table 8 Function and resource form requirements

Subject	Not needed at all	Slightly not needed	Neutral	Needed	Very much needed
Microlearning resources	0%	1.98%	13.86%	48.51%	35.64%
Text-based and visual resources	0%	0.99%	12.87%	50.5%	35.64%
Information resources	0%	1.98%	22.77%	55.45%	19.8%
Categorized links to commonly used AI education tools and platforms.	0%	1.98%	11.88%	52.48%	33.66%
Channels/links for downloading related resources or files.	0%	2.97%	11.88%	45.54%	39.6%
Educational and instructional AI agents.	0%	0.99%	28.71%	47.52%	22.77%
Online workshops	0%	1.98%	27.72%	48.51%	21.78%
Interactive display functions	0.99%	0.99%	16.83%	53.47%	27.72%
Online assessment functions	0.99%	1.98%	16.83%	50.5%	29.7%
Learning evaluation functions	1.98%	0.99%	16.83%	52.48%	27.72%

Discussions

The current status of AI learning for rural primary and secondary school teachers: from fragmented exposure to the need for systematic development. This study found that rural primary and secondary school teachers have generally begun to engage with AI-related content, exhibiting a relatively positive learning attitude and strong intrinsic motivation. The survey results show that most teachers believe learning AI-related educational content helps improve their teaching abilities and efficiency, respond to professional development needs, and broaden their knowledge horizons. This indicates that against the backdrop of rapid development of generative AI and the continuous advancement of digital transformation in education, some teachers’ understanding of AI is no longer limited to external policy requirements or passive adaptation, but is gradually shifting towards proactive learning based on professional development and teaching improvement needs (Nikolic et al. 2024). These finding echoes previous research, suggesting that the improvement of AI literacy among primary and secondary school teachers has a solid subjective foundation; that is, teachers do not lack the desire to learn, but rather lack systematic, continuous, and contextualized learning support (Huang, 2023).

From the perspective of learning methods, rural teachers’ AI-related learning is characterized by fragmentation, mobility, and informality. Smartphones are the primary device for teachers to conduct online learning, and short video platforms and WeChat public accounts have become important channels for rural teachers to acquire AI educational knowledge. This result reflects a change in the current professional

learning methods of teachers. Compared to traditional centralized training and more formal online courses such as MOOCs or SPOCs, teachers tend to utilize fragmented time to quickly acquire knowledge that can be directly transferred to teaching practice through short videos, text and image pushes, tool cases, and operation demonstrations (Shi, 2024). In other words, rural teachers not only need "systematic and complete theoretical courses," but also an online learning environment that balances systematicity and flexibility. This means providing a structured framework for AI literacy while also meeting teachers' immediate, practical, and personalized learning needs through micro-lessons, case studies, toolkits, and task-driven activities.

While most rural teachers hold a positive attitude towards AI-enabled education and have a high sense of self-efficacy regarding their learning and knowledge transfer abilities, they also point out that the main difficulties in learning and applying AI are the lack of systematic training and guidance, insufficient learning time, a lack of AI tools suitable for subject teaching, and concerns about the accuracy and reliability of AI-generated content. Therefore, the key obstacle to the development of rural teachers' AI literacy does not entirely stem from individual teachers' attitudes or insufficient abilities, but rather from the mismatch between learning resources, training mechanisms, technical support, and application contexts. Existing research has also pointed out that short-term, lecture-style, and one-off training programs are often insufficient to effectively support teachers in developing stable technology integration capabilities (e.g., Author & Author, 2026; Younis, 2024). Therefore, the design of relevant training programs and online learning environments should fully take into account regional disparities, school conditions, and teachers' authentic work contexts, rather than equating technological accessibility with technological effectiveness.

Teachers' willingness to accept and use AI: a mix of positive attitudes and real-world obstacles. Drawing on the UTAUT model, this study examined rural primary and secondary school teachers' acceptance of and intention to use AI technologies from the four dimensions. The results showed that the scores for all four dimensions were significantly higher than the theoretical midpoint, indicating that teachers generally held positive attitudes toward AI-empowered education. This finding is also consistent with previous studies. In the context of ongoing educational digital transformation and the rapid development of generative AI, rural teachers have gradually recognized the potential value of AI in improving classroom teaching quality, optimizing instructional management, promoting personalized learning, and supporting teachers' professional development (Ng et al. 2024).

First, in terms of performance expectancy, most rural teachers believed that AI could enhance classroom teaching effectiveness and work efficiency. This suggests that rural teachers' acceptance of AI technology remains strongly problem-solving oriented; that is, they are primarily concerned with whether AI can effectively respond to authentic needs in teaching practice. For example, AI can assist teachers in developing courseware, generating exercises, designing classroom activities, conducting learning analytics, providing personalized learning support, optimizing assignment grading, and improving instructional feedback (e.g., Author & Author, 2024; Author & Author, 2026). This finding is consistent with existing research on teachers' technology acceptance, which suggests that when teachers perceive technology as having a positive impact on teaching performance and work efficiency, they are more likely to develop sustained intentions to use it (Xue et al. 2026). Therefore, AI training for rural teachers should not remain at the level of abstract conceptual explanation or simple technology demonstration. Instead, it should be

organized around real problems in rural teachers' everyday teaching practice, such as "how to use AI to prepare lessons efficiently", "how to use AI to generate differentiated assignments", "how to evaluate the reliability of AI-generated content" and "how to transform AI outputs into usable classroom resources".

Second, in terms of effort expectancy, although rural teachers recognized the educational value of AI, they also generally believed that learning and applying AI required considerable time and effort. This included repeatedly testing and adjusting tools, understanding prompt design, screening and revising generated content, adapting instructional procedures, and responding to uncertainties in classroom implementation. This finding indicates that teachers' attitudes toward AI are neither simply positive nor negative; rather, they reflect a coexistence of value recognition and concerns about cost. In other words, rural teachers are willing to learn and use AI, but only when they can perceive a reasonable relationship between the time invested and the instructional benefits gained. Therefore, teacher training should aim to lower the threshold for technology use by providing operational templates, subject-specific cases, prompt examples, and classroom application procedures that can be directly transferred into practice (Walter, 2024). At the same time, training should help teachers recognize that the initial learning costs may later be transformed into greater efficiency in lesson preparation, assessment, and resource development, thereby strengthening their confidence in the sustained use of AI (Author & Author, 2026).

Third, in terms of social influence, rural teachers generally perceived that schools, society, and students supported the integration of AI into teaching. This suggests that the external policy environment, school culture, and student needs are becoming important forces driving the development of rural teachers' AI literacy. In recent years, policy discourses related to educational digital transformation, smart education platforms, and AI-empowered education have been continuously reinforced (Ding et al. 2024), enabling teachers to develop a clearer understanding of the professional value and developmental trends of AI (Lintner, 2024). Meanwhile, students' interest in and acceptance of intelligent tools have also encouraged teachers, to some extent, to explore the integration of AI into teaching practice (Ke et al. 2025). However, social influence does not necessarily translate into actual action. Only when schools provide institutional support, resource support, technical support, and evaluation incentives can external advocacy be transformed into teachers' practical engagement. Therefore, at the school level, organizational mechanisms should be established to support the development of teachers' AI literacy, such as building teacher AI professional learning communities, conducting school-based professional development, providing case libraries and tool repositories, encouraging interdisciplinary collaboration, and incorporating AI application competence into teacher professional development support systems, rather than simply turning it into an additional workload for teachers (Palmquist et al. 2026).

Finally, in terms of facilitating conditions, the difficulties most frequently reported by teachers included a lack of timely and effective technical support, insufficient high-quality AI teaching resources, inadequate knowledge and skills, and unequal resource allocation caused by regional economic disparities. This indicates that the improvement of rural teachers' AI literacy cannot rely solely on individual teachers' learning initiative; instead, it requires systematic support. Complex dynamic systems theory suggests that teachers' technology application behaviors emerge from interactions within multi-level systems (Zheng et al. 2020): at the micro level, these behaviors involve teachers' individual knowledge, attitudes, and skills; at the meso level, they are shaped by school resources, technical support, and professional

learning cultures; and at the macro level, they are influenced by regional policies, educational resource allocation, and the broader sociotechnical environment. Therefore, efforts to enhance teachers' AI literacy should adopt a multi-level and coordinated approach, attending not only to the development of individual teachers' competencies but also to the construction of supportive conditions at the school, regional, and policy levels.

The AI learning needs of primary and secondary school teachers: from tool training to integrating teaching and professional development. This study further reveals that rural teachers' needs regarding AI learning environments are primarily concentrated in two areas: classroom teaching applications and professional development. Among these needs, the use of AI to efficiently develop teaching resources emerged as the most prominent, followed by AI-supported teaching management, general AI knowledge, AI-assisted instructional design, student learning analytics, and personalized instruction. These findings suggest that teachers' needs for AI are not limited to acquiring general technical knowledge. Rather, teachers are more concerned with how AI can be transformed into a practical professional tool that directly supports their everyday teaching work (Ding et al. 2024; Younis, 2024).

Theoretical and practical implications. Theoretically, this study demonstrates that the development of rural teachers' AI literacy is not a simple accumulation of individual teachers' knowledge and skills, but rather the result of the interaction of multiple factors, including teachers, technology, schools, students, resources, policies, and the social environment (Zheng et al. 2020). Therefore, future research should move beyond a static competency framework and understand teachers' AI literacy as a dynamic competency that is continuously generated, adjusted, and developed within specific teaching contexts. Especially in the context of the rapid iteration of generative AI, the framework for teachers' AI literacy should also be open and developmental, capable of responding to continuous updates in response to technological changes, evolving teaching needs, and ethical challenges in education (Ng et al. 2024; Saqr et al. 2025).

In practical terms, this study offers several implications for AI training and the development of online learning environments for primary and secondary school teachers. First, the goals of training should shift from "tool use" to "pedagogical integration", helping teachers meaningfully embed AI into the entire process of lesson preparation, classroom instruction, assessment, management, and professional development. Second, training content should move beyond the delivery of general knowledge and provide differentiated support according to teachers' subject areas, educational levels, technological backgrounds, and application scenarios. Third, training formats should shift from short-term intensive workshops to sustained online learning communities, in which teachers' long-term development is supported through microlearning resources, case-based tasks, online workshops, interactive Q&A, and practice-based feedback. Fourth, training evaluation should move beyond course completion or certificate acquisition and focus instead on authentic teaching outcomes, including whether teachers are able to design AI-integrated instructional activities, evaluate the quality of AI-generated content, address ethical and safety issues, and continuously reflect on and improve their practice. Fifth, regional and school-level support conditions should be strengthened, particularly by providing teachers in relatively under-resourced areas with high-quality, low-threshold, and sustainable AI educational resources and technical support, so as to prevent the application of AI

from further widening educational disparities.

Conclusions

This study examined the current status, technology acceptance, barriers, and professional learning needs associated with AI literacy among rural primary and secondary school teachers. The findings show that rural teachers are not resistant to AI. On the contrary, they generally display strong intrinsic motivation, positive attitudes, relatively high self-efficacy, and a clear recognition of AI's potential to improve teaching and work efficiency. At the same time, their current learning is frequently fragmented, mobile, and informal, relying heavily on smartphones, short videos, and social media channels. Although most teachers have acquired some awareness and knowledge of AI, a persistent knowledge–practice divide limits their ability to transform that knowledge into sustained and pedagogically meaningful classroom use.

The UTAUT-based results further demonstrate that rural teachers' acceptance of AI is shaped by the simultaneous interaction of perceived value, learning costs, social expectations, and facilitating conditions. Teachers expect AI to support resource development, instructional design, assessment, management, learning analytics, and professional development, but they also face substantial demands related to time, repeated experimentation, prompt design, content verification, technical support, and access to high-quality subject-specific resources. Thus, positive attitudes alone are insufficient to ensure meaningful adoption. From a CDST perspective, teachers' AI literacy should be understood as a dynamic and context-dependent competence that emerges through interactions among teachers, technologies, pedagogical tasks, students, schools, policies, resources, and regional conditions.

These findings indicate that future AI literacy initiatives should move beyond short-term tool demonstrations and adopt a systematic, flexible, differentiated, and practice-oriented approach. Training should be organized around authentic teaching problems and provide subject-specific cases, reusable prompts and templates, concise microlearning resources, opportunities for collaborative inquiry, expert feedback, and sustained school-level technical and organizational support. Evaluation should focus on teachers' ability to design AI-integrated learning activities, critically assess AI-generated content, protect privacy and academic integrity, and improve practice through reflection, rather than merely on course completion or certificate acquisition. Particular attention should also be given to teachers and schools in under-resourced regions so that AI-supported education does not intensify existing inequities. Overall, the study provides an empirical foundation for developing online professional learning environments that connect AI knowledge with pedagogical practice and support the continuous development of teachers' AI literacy.

Several limitations should be acknowledged. First, the questionnaire sample was relatively small and unevenly distributed across school levels, subjects, genders, and regions. Although participants were recruited from different parts of China, the findings should be interpreted as exploratory rather than nationally representative. Future studies should employ larger, stratified samples and compare teachers across regions, school types, subject areas, and levels of technological infrastructure. Second, the study relied mainly on self-reported questionnaire and interview data. Teachers' stated confidence, intentions, and needs may not fully correspond to their actual classroom behavior or level of AI competence. Future research should triangulate self-reports with classroom observations, platform logs, teaching artifacts, performance-based AI literacy assessments, and longitudinal evidence of technology

integration. Third, the present study identifies training needs but does not test the effectiveness of a specific professional development intervention. Future research should use design-based research or quasi-experimental approaches to develop and evaluate the proposed learning environment. Such work should examine not only immediate gains in knowledge and attitudes, but also sustained classroom integration, ethical decision-making, effects on teaching quality and student learning, and the conditions under which training can be scaled across diverse educational contexts.

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Competing interests
The authors declare no competing interests.

Ethical approval
All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Institutional Review Board of the Southwest University Faculty of Education (protocol code 2025ZXYB29) on December 31, 2025. The study was approved by the Khon Kaen University Ethics Committee for Human Research (Reference No. HE693105; Institutional Review Board Number IRB00012791; Federal Wide Assurance FWA00003418) on May 20, 2026.

Human ethics and consent to participate declarations
In compliance with national regulations and institutional standards, the corresponding author and the first author obtained written informed consent from participants prior to data collection, beginning on January 17, 2026. Participants received clear information about the study's purpose, procedures, and voluntary nature, including (a) the right to withdraw at any time without penalty; (b) confidentiality: all personal information provided by participants was kept strictly confidential and was neither published nor disclosed, and (c) use of data: the data collected from participants was used solely for academic research purposes and was not employed for any commercial activities. The process of obtaining informed consent involved the following steps: (a) researchers provided informed consent forms to participants during their visits to the school and explained the content in detail; and (b) for participants who were unable to come to the school, the researchers explained the content of the forms to the participants via video conferencing. The study employed a noninterventional research design using anonymous paper-based questionnaires. Therefore, the informed consent statement included the following elements: (a) anonymity and confidentiality were guaranteed, and no personally identifiable information was collected; (b) the purpose of the study was clearly explained, namely, to investigate the current status of AI-related learning among

rural primary and secondary school teachers, their acceptance of AI technologies, the difficulties they encounter, and their preferred learning content and resource formats. The study would be used for academic purposes and not for any commercial use; (c) participants were informed that there were no foreseeable risks associated with participation; and (d) all data collected were used for academic research and not employed for any commercial activities. Informed consent date: February 15, 2026.

Data availability

The data and materials supporting the findings of this study are available in the Supplementary Material accompanying this article. The shared materials include the survey instruments and protocols, the de-identified raw survey data, the processed and analyzed survey data, the interview guides, the de-identified interview transcripts, and documentation of the data analysis procedures.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- InterviewdataChineseandEnglishversion.docx
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- surverydatabothrawandprocessedversions.xlsx
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