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Review

Intelligent Tutoring System for Teachers' Digital Competence Improvement in China: A Systematic Literature Review

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Abstract: This paper conducts a systematic review of quantitative empirical studies from 2020 to 2025 on the integration of teacher digital competence enhancement with intelligent tutoring systems (ITS). A total of 84 high-quality academic articles were selected based on the PRISMA process. The focus is on the mechanisms through which diagnostic-push ITS influence teachers' digital skill development, with analyses grounded in key theories such as DigCompEdu, TPACK, and the Technology Acceptance Model. Central issues including teachers' technological self-efficacy, classroom technology integration, and instructional innovation are explored. The study found that most intelligent tutoring systems enhance teachers' digital adaptability in instructional design and classroom operations by leveraging feedback functions within learning management systems, artificial intelligence recommendations, and personalized intervention strategies. Notably, there was significant improvement in teachers' digital self-efficacy. Additionally, school organizational culture and information and communication technology (ICT) resources emerged as important moderating variables influencing the effectiveness of these systems. This paper constructs a causal model of "platform-capability-performance," providing theoretical guidance and practical suggestions for cultivating teachers' capabilities in a digital educational environment. It also identifies the design flaws of current intelligent tutoring systems and future research topics, emphasizing the importance of localization adjustments and long-term evaluation.

Keywords: teacher digital capabilities; intelligent tutoring systems; self-efficacy; PRISMA process; teaching innovation

1. Introduction

1.1. Problem Statement

The digital transformation of education has become a core trend in global educational development and a key strategic path for China to build an education powerhouse and achieve educational modernization (Lin et al., 2023). As the leaders of the educational process and practitioners of educational reform, teachers' digital literacy directly determines the depth, breadth, and effectiveness of educational digital transformation (Oliveira et al., 2022). To date, intelligent tutoring systems (ITS) in artificial intelligence have been widely applied in the field of education and are already being used in areas such as personalized learning support, adaptive teaching recommendations, and teaching feedback optimization (Bernacki et al., 2021; Hardy et al., 2019). Their core advantage lies in their ability to analyze behavioral data of teachers or learners through intelligent algorithms, enabling dynamic assessment and intelligent intervention to help users enhance their cognitive and skill levels in diverse teaching scenarios (Drigas & Karyotaki, 2014).

In the context of the global digital transformation of education, many countries and educational institutions have regarded the improvement of teachers' digital capabilities as an important direction of



education development. For example, in European countries, where integrated technology approaches to student registration, the teaching profession will play a greater role (Gabriel et al., 2022). In China, more attention has been paid to the construction of digital policy platforms to alleviate the teaching pressure of primary and secondary school teachers (Yang et al., 2025). Although there have been studies on teacher training, information literacy assessment, and the use of digital platforms, there are still limited studies that systematically focus on "teachers' digital competence improvement" and the combination of "intelligent tutoring systems", especially in terms of technical paths, system architectures, intervention mechanisms, and evaluation models, etc., which lack systematic combining and theoretical framework support (Hammons, 2020; Hase & Kuhl, 2024).

Therefore, this paper aims to conduct a systematic review of recent domestic and international literature on "intelligent tutoring systems for enhancing teachers' digital capabilities," summarize the core technical pathways, design patterns, and evaluation indicators of existing research, analyze the current state of research and existing issues, and propose future trends and research directions to provide theoretical basis and practical references for constructing a more intelligent, precise, and efficient teacher capability enhancement support system (Hannan et al., 2015). This review focuses on the four-stage development path of teachers' digital competencies in the Chinese context: acceptance, integration, innovation, and leadership, and identifies the key role of intelligent tutoring systems (ITS) in this process. Existing research has generally confirmed that diagnostic-push ITS, such as LMS feedback modules and AI recommendation tools, can effectively enhance teachers' digital self-efficacy, a variable that plays a complete mediating role in path analysis. ITS has a significant promotional effect on classroom technology integration and instructional design innovation, particularly in TPACK-oriented training and AI-Coach mechanisms. Furthermore, school culture and technological resources have been identified as important moderating variables influencing intervention effectiveness. In recent years, ITS research has expanded to include multi-modal systems such as data dashboards and virtual simulations, marking a shift in research focus from tool efficacy to ecological adaptation. Overall, the supportive role of ITS in teacher professional development has become evident, but there remains room for expansion in areas such as localization design, cross-disciplinary adaptation, and behavioral tracking depth.

1.2. Systematic Review

The Joint Information Systems Committee (JISC) (2024) developed a digital capability framework, defining digital competence as the ability of an individual to be able to survive in a digitized environment, which encompasses digital proficiency and productivity, information, data and media literacies, digital creation, problem solving and innovation, digital communication, collaboration and participation, digital learning and development and digital identity and wellbeing. As the global education digitization process accelerates, digital competence is not only regarded as a key component of teacher professional development but also serves as an important indicator for evaluation and intervention within the education system. Currently, the most influential framework internationally is the EU's DigCompEdu (Digital Competence Framework for Educators), which divides teachers' digital literacy into six dimensions: professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and promoting learners' digital literacy. Each dimension is further broken down into 22 capability indicators (Hannan, 2017). DigCompEdu provides clear grading standards, offering a theoretical basis for teacher training and policy development.

Traditional ITS research has focused on personalized learning for students, but in recent years, an increasing number of studies have begun to explore its potential applications in teacher professional development and capability enhancement (Ma et al., 2014). Létourneau et al. (2025) conducted a comprehensive evaluation of multiple experimental studies in K-12 education and pointed out that the core function of intelligent tutoring systems (ITSs) lies in providing personalized learning path support for students, while also offering valuable insights for teachers in instructional design and technology adoption. Cade et al. (2023) found that integrating ITS with teacher digital competency development can effectively achieve an integrated "assessment-training-testing" support process.

2. Method

2.1. PRISMA

To ensure the rigor and reproducibility of the review process, this study followed the PRISMA-2020 statement and divided the literature selection into four stages: identification, screening, eligibility, and inclusion (Moher et al., 2009). Figure 1 illustrates the literature selection process. A total of 3,829 records were identified using search keywords in Chinese and English databases. Using EndNote 20 and regular expression scripts, titles, DOIs, and publication sources were compared to exclude 589 duplicate entries. The remaining 3,240 records underwent an initial screening of titles and abstracts. Following the PICOS

principles, 2,790 records that did not align with the theme or had unclear methodologies were excluded. The full texts of 450 records were subjected to a thorough review. Based on the inclusion/exclusion criteria, studies focusing on Chinese teachers, digital literacy, and ITS platforms were retained, resulting in 84 high-quality studies. The inter-rater reliability coefficient (Cohen's k) between the two reviewers was 0.87, indicating high consistency in the screening process.

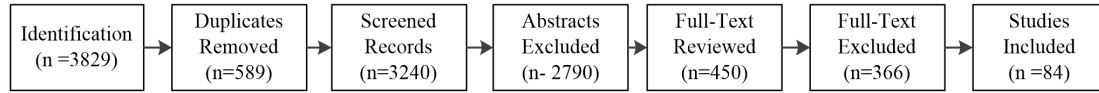


Figure 1. Literature selection process.

2.2. Resources

The search resources include Web of Science, Scopus, ERIC, CNKI, and Google Scholar. The search period is limited to 2020–2025, and the document types are academic journal articles and books. The number of hits, coverage period, and fields for each database are shown in Table 1. The final samples are all sourced from international databases, with Google Scholar accounting for the largest proportion, reflecting the balanced coverage of this review.

Table 1. Number of hits, coverage years and fields of each database.

Database	Coverage(Year)	Hits	Fields Searched
Web of Science	2020-2025	980	Title/Abs/Key
ERIC	2020-2025	240	Title/Abs/Key
Scopus	2020-2025	960	Title/Abs/Key
CNKI	2020-2025	529	Title/Abs/Key
Google Scholar	2020-2025	1120	Title/Abs/Key

2.3. Systematic Review Process

The inclusion and exclusion criteria for the four stages are shown in Table 2. The systematic literature review is divided into four stages: identification, screening, eligibility, and inclusion, with reproducible operational details set for each stage.

Table 2. Inclusion and exclusion criteria for the four stages.

Stage	Core operations	Result
Identification	Design search formulas based on three sets of concepts; search in Web of Science, Scopus, ERIC, CNKI, and Google Scholar.	3829
Deduplication	Using EndNote 20 and Python regular scripts, we compared DOI, title, and ISSN and removed 589 duplicate entries.	3240
Screening	Eliminate irrelevant research (1) 2020-2025; (2) Original research in journals; (3) Focus on teachers; (4) Research location is China; (5) Involve digital capabilities or ITS.	450
Eligibility	114 articles whose assessment tools did not match the research questions were excluded; 152 articles that only involved students or administrators were excluded; 100 articles that lacked methodological details were excluded; 84 articles whose language did not meet the requirements were excluded	84
Quality	The MMAT-2018 and AXIS tools were used to score the studies based on	84

Assessment	five dimensions: research design, sample description, data collection, bias control, and consistency of conclusions.	
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2.4. Data Analytic Strategy

To construct a cause-and-effect framework for the system, the four stages of teachers' digital competence—acceptance, integration, innovation, and leadership—correspond to ITS diagnosis, promotion, reshaping, and diffusion, as well as key performance indicators such as performance, efficiency, cooperation, and innovation. Data analysis adopts a parallel mixed strategy of “quantitative measurement + qualitative themes,” and the overall approach follows an integrative review method.

3. Results

Most quantitative studies on “Chinese Teachers' Digital Competence and Intelligent Tutoring Systems (ITS)” have focused on diagnostic-push platforms. Among all the samples, nine articles evaluated how LMS-integrated diagnostic modules enhance teachers' digital self-efficacy (Cukurova et al., 2023; Hizam et al., 2021; Linde et al., 2023; Liu et al., 2025). Four articles compared the differences between Adaptive ITS and traditional training in terms of classroom technology integration (Zhao et al., 2021; Wang et al., 2023; Sajja et al., 2023; Liu et al., 2025), while 5 focused on the promotional role of AI Coach functions in fostering instructional design innovation (Zhao et al., 2021; Li et al., 2025; Dickey & Bejarano, 2023; Wang & Demuszky, 2023; Jiang et al., 2025). Four articles respectively explored the comprehensive effectiveness of Analytics Dashboards, VR/Simulation, and Hybrid platforms, indicating that research perspectives are expanding from single tools to multi-modal ecosystems (Prinsloo et al., 2022; Ramaswami et al., 2023; Echeverría et al., 2024; Wiley et al., 2024; Sakr & Abdullah, 2024).

Figure 2 presents a causal framework of ITS's impact on teachers' digital competence, showing a sustained upward trend over time. Based on Passmore and Woodward's causal framework, this study identified exogenous variables such as teacher background and platform functionality, moderating variables such as school culture and technological resources, mediating variables such as digital self-efficacy and learning motivation, and confounding variables such as subject, class size, four-stage scores, collaboration index, and innovation level (Passmore & Woodward, 2023). Digital self-efficacy fully mediates the positive impact of ITS feedback on classroom innovation, while school culture has a significant moderating effect on this mediating path (Radecki et al., 2021).

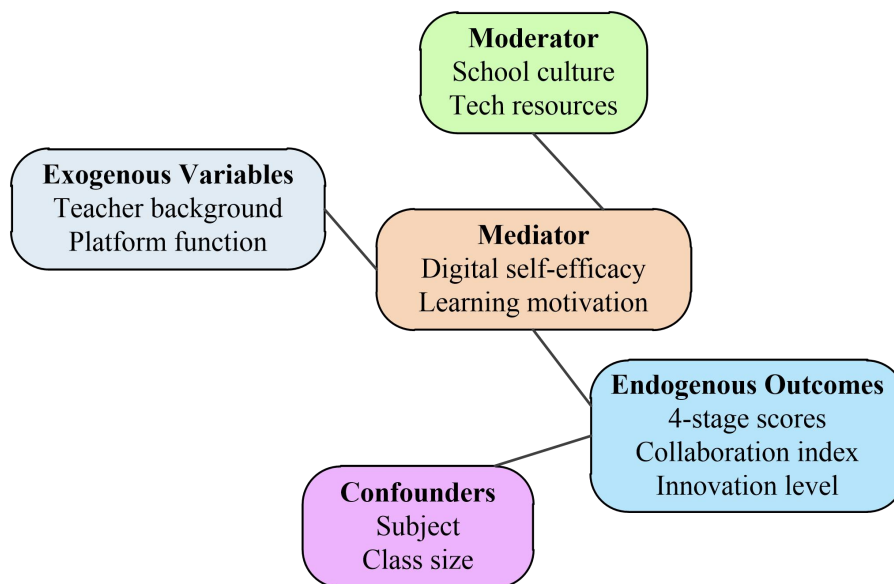


Figure 2. Causal framework of ITS’ impact on teachers’ digital competence.

Table 3 shows the variable categories, representative sub-variables, supporting research, teacher background, and platform characteristics that influence the final outcome, 4-stage scores, collaboration index, and innovation through “digital self-efficacy/learning motivation.” This was verified in five structural equation studies. School culture and ICT resources significantly enhance the strength of the ITS feedback → self-efficacy path. Only three studies simultaneously controlled for subject/class size,

suggesting that future models should further incorporate differences in classroom size.

Table 3. Variable Categories, Representative Sub-Variables, Supporting Studies.

Variable Type	Article topic	Author	Title
Exogenous	Teacher age	Santana-Monagas et al., (2022).	Teachers' engaging messages: The role of perceived autonomy, competence and relatedness
	Teaching experience	Njuguna et al., (2025).	The extent to which teachers' attitudes and beliefs influence ICT use in teaching among public secondary school teachers in Kipipiri Constituency
Mediator	Digital self-efficacy	Maran et al., (2022).	Who fits into the digital workplace? Mapping digital self-efficacy and agility onto psychological traits
	Intrinsic motivation	Lai et al., (2021).	Why people join pro-Ana online communities? A psychological textual analysis of eating disorder blog posts
Moderator	School culture	Radecki et al., (2020)	Interactive sonification of images in serious games as an education aid for visually impaired children
	ICT infrastructure	Lomos et al., (2023).	Implementing ICT in classroom practice: what else matters besides the ICT infrastructure?
Confounder	Subject domain	Fackler et al., (2021).	An international perspective on teacher self-efficacy: personal, structural and environmental factors
	Class size	Althubyani, (2024)	Digital competence of teachers and the factors affecting their competence level: A nationwide mixed-methods study. Sustainability
Endogenous	competence score	Aydin et al., (2024)	Teachers' digital competences: a scale construction and validation study
	Collaboration index	Prinsloo et al., (2022)	The answer is (not only) technological: Considering student data privacy in learning analytics
	Innovation level	Orak and İnözü, (2021).	Teachers' Awareness and Actual Practices of 21st Century Learning and Innovation Skills.

4. Discussion

This study employs a systematic literature review to summarize the core findings of recent domestic and international research on the integration of teacher digital competency enhancement and intelligent tutoring systems (ITS). The analysis is conducted from three perspectives: system functional types,

competency development dimensions, and variable structural logic:

(1) The application of ITS in teacher development is still in its early stages, with most research focusing on diagnostic push functions, such as diagnostic modules in learning management systems and recommendation systems, all aimed at enhancing teachers' information technology self-efficacy and their ability to integrate teaching technology into the classroom (Sáiz-Manzanares et al., 2022). Although a few studies have begun to explore new ITS functionalities such as AI coaches, simulation platforms, and multimodal dashboards, current systems primarily focus on single-dimensional interventions and have not yet established a comprehensive growth guidance system spanning the entire teacher career trajectory. Yang et al. (2025) utilized the TPACK model of teacher professional development to demonstrate that AI-assisted design can help teachers better integrate information technology with instructional objectives. However, Yoo et al. (2022) noted in their research on deep learning models that if ITS systems could simultaneously collect teachers' classroom behavior data and digital cognitive trajectories, the system's responsiveness and personalized feedback pathways would be significantly expanded.

(2) From the perspective of the top ten high-frequency research themes, digital self-efficacy, classroom technology integration, and teaching performance constitute the research focus, accounting for the majority of literature analysis frameworks (Yoo et al., 2022; Sari et al., 2022). These themes highly overlap with the “teaching-assessment-collaboration” capability dimensions, indicating that teachers generally focus on “whether they can effectively utilize technology.” Additionally, themes such as collaborative community building and data literacy, which fall under the “collaboration-leadership” category, are gradually entering the research landscape, reflecting teachers' practical need to transition from “individual efforts” to “organizational collaboration” (Zhang & Lin, 2020; Ndukwe & Daniel, 2020).

(3) Based on variable statistics, teachers' digital self-efficacy plays a central mediating role in ITS intervention pathways, indirectly driving improvements in teachers' performance in areas such as classroom technology integration and instructional design innovation (Clipa et al., 2023; Fan et al., 2023). This also validates the applicability of self-efficacy theory, which posits that individuals' “belief in their ability” to use digital technology significantly influences their willingness to adopt new behaviors. Meanwhile, in terms of moderating variables, “school culture” and “technological infrastructure” were found to have significant influences in three structural equation modeling studies (Ma & Green, 2023), further reinforcing the notion that teacher growth depends not only on individual capabilities but also on institutional support and cultural context.

5. Limitations and Recommendations

Although this paper provides a comprehensive systematic review of the current state of research on enhancing teachers' digital competencies in conjunction with intelligent teaching systems (ITS), it is essential to identify and address the limitations of existing research. Specifically, the following points should be considered:

(1) This paper focuses on the development of teachers' digital literacy in the Chinese context. However, the technological origins of most of the intelligent teaching system platforms cited in this paper still stem from Europe and the United States. Many of the functional designs and intervention measures of these systems do not fully align with the complex educational environment of Chinese primary and secondary schools. Such technological transfers can easily lead to application discrepancies, and caution should be exercised when interpreting research outcomes. Therefore, Chinese education technology companies and research institutions should develop intelligent teaching systems tailored to the national context based on the stages of teachers' professional development, the cultural characteristics of teaching, and the specific requirements of classroom instruction. For example, factors such as curriculum reform, assessment systems, and teaching workload should be considered to promote the establishment of a “teacher digital twin” data model. This would enhance the system's environmental adaptability and make it more aligned with the national culture (Iliuță et al., 2024).

(2) Although all the adopted studies are quantitative in nature, there are significant differences in study design, tool selection, sample size, and the statistical models used. Some studies employed structural equation modeling to explore mediating effects, while others used t-tests or regression models to evaluate outcomes, making cross-comparisons challenging and complicating the establishment of a unified outcome measurement system. Future research should adopt more complex statistical techniques, such as multilevel linear models (MLM), latent variable structural models (SEM), or Bayesian networks, to elucidate the dynamic relationships between teacher background, intelligent teaching system functionality, and student digital performance. Additionally, mixed-methods research should be encouraged, incorporating data from multiple sources such as interviews, behavioral records, and teaching videos to enhance the reliability of the research.

(3) Most studies are based on short-term interventions and lack follow-up data beyond six months.

The development and application of teachers' digital competencies require long-term accumulation and practical feedback to be fully realized, so existing literature cannot adequately demonstrate sustained effects or transfer effects. Furthermore, studies implementing intelligent teaching systems in actual teaching environments are rare, which limits the external validity of research. Researchers should be encouraged to conduct surveys in rural areas, ethnic minority-populated regions, and remote schools to analyze the feasibility of intelligent teaching system interventions under conditions of unequal educational resource distribution and identify improvement methods. Furthermore, since different disciplines have varying degrees of reliance on technology, it is necessary to strengthen interdisciplinary comparative research.

6. Conclusion

After a systematic review of the literature, this paper concludes that ITS plays a significant role in enhancing Chinese teachers' information technology proficiency, particularly in strengthening teachers' digital self-efficacy, promoting the integration of technology into classroom teaching, and driving innovations in instructional design. Theoretical models such as DigCompEdu and TPACK have been frequently cited in previous studies, validating the corresponding relationships between different levels of information technology proficiency and the various functions of ITS. However, most current ITS-related research focuses on short-term impact analysis and technical performance evaluation, lacking long-term tracking of teachers' personal development. Additionally, existing systems are primarily developed based on Western cultural contexts and educational systems, so their adaptability to local cultures and alignment with domestic educational environments still require improvement. Future research should prioritize developing the environmental sensing capabilities of ITS systems, fostering collaboration among platforms, and establishing a feedback loop regulation system based on behavioral data analysis. It should also address the imbalance of educational resources across regions to achieve equitable access to digital education. This work not only provides theoretical guidance for teacher training strategies and learning platform design but also holds practical significance for creating an intelligent, ecological, and personalized teacher assistance system.

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Database	Coverage(Year)	Hits	Fields Searched
Web of Science	2020-2025	980	Title/Abs/Key
ERIC	2020-2025	240	Title/Abs/Key
Scopus	2020-2025	960	Title/Abs/Key
CNKI	2020-2025	529	Title/Abs/Key
Google Scholar	2020-2025	1120	Title/Abs/Key