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Exploring Chinese teachers' concerns about teaching artificial intelligence: the role of knowledge and perceived social good

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Abstract
This study aimed to investigate the factors accounting for Chinese teachers' concerns about teaching artificial intelligence (AI). Based on the concerns-based adoption model and the pedagogical content knowledge framework, a hypothesized model associating teachers' knowledge, perceived social good, and concerns about teaching AI was tested via structural equation modelling. The responses from 269K-12 AI teachers in southern China were utilized to test the hypothesized model. Structural equation modelling reveals that the association between teachers' knowledge of teaching AI and teachers' concerns about teaching AI is mediated by teachers' perceived social good of teaching AI. Particularly, teachers' perceived social good of teaching AI partially mediated relationships between teachers' pedagogical AI knowledge and refocusing concern, as well as teachers' conceptual AI knowledge and management concerns. These findings provide a more profound understanding of teachers' perceived social good as a pedagogical belief. The results show that teachers' knowledge (i.e. pedagogical AI knowledge and conceptual AI knowledge) predicted higher stages of concern (i.e. refocusing and management) when mediated by teachers' perceived social good of teaching AI. This study contributes to a better understanding of factors contributing to teachers' concerns about teaching AI, and how to address them for teacher professional development.

Keywords Concerns · Knowledge · Social good · Artificial intelligence · Teacher professional development

Introduction

In recent years, artificial intelligence (AI) has opened up new opportunities for education administration, instruction, and learning (Chen et al., 2020, 2022; Guo et al., 2021). Efforts are underway in many countries to promote AI education for K-12 students (Touretzky et al., 2019). A growing number of teacher professional development activities are aiming to facilitate effective teaching of the AI curriculum (Aler Tubella et al., 2024; Casal-Otero et al., 2023). Specifically, key purposes of AI teachers' professional development are to reconstruct the AI curriculum, to implement and assess mastery of specific pedagogical strategies in the field of teaching AI (e.g., providing K-12 students with concrete pedagogical examples), and to develop students' social learning and shape their values with suitable pedagogy (Aler Tubella et al., 2024; Chai et al., 2023; Song & Wang, 2020). Although teachers

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play irreplaceable roles in educational reform, they may feel negative emotions (e.g., fear, frustration, and resistance to such efforts) about the reform process because of the complex challenges, including external difficulties in their teaching environment, insufficient support in the current AI curriculum design, and intrapersonal obstacles in their beliefs about teaching AI (Su et al., 2022). Among the numerous studies examining teachers' attitudes, emotions, and intentions regarding educational reform, concern is a mature term that can be regarded as a foundation for helping teachers change from passive participants (e.g., a resister or opponent) to active innovators in education reform (Lambriex-Schmitz et al., 2020).

Teachers' concerns about educational innovation have important impacts on the implementation process (Fullan, 2007; Hall & Hord, 1987). Researchers have been trying to identify teachers' concerns about innovation and reform, such as teachers' feelings, thoughts, and considerations about teaching (Byrne & Prendergast, 2020; Teerling et al., 2020). Past studies have advocated that understanding teachers' concerns serves as a foundation for educators to facilitate teachers' adaption (Zhang et al., 2014). To evaluate teachers' concerns about innovation, the concerns-based adoption model (CBAM) developed by Hall and Hord (1987) was frequently applied as a theoretical framework (Al-Furaih & Al-Awidi, 2020). Researchers specifically applied the stage of concern (SoC) questionnaire as a tool from CBAM to measure teachers' concerns of different stages (e.g., awareness, information, personal, management, collaboration, refocusing) and its influence factors (Dele-Ajayi et al., 2021; Hao & Lee, 2015). Previous studies applied CBAM to measure teachers' concerns in conventional teaching contexts (Dele-Ajayi et al., 2021; Yan & Deng, 2018).

In AI curriculum reform more specifically, research on teachers' concerns is still limited as most studies in the field have focused more on teachers' perceived support perspectives such as teaching resources, devices, design frame, and teacher professional development program, and so on (Velander et al., 2023; Yau et al., 2023). Considering teachers' concerns about participating in teaching AI reform, Lin et al. (2022) attempted to conceptualize a teachers' concerns framework from interview data; they identified two aspects: (1) Intrapersonal obstacles and facilitators, and (2) extrinsic obstacles and facilitators. However, while the framework offered a conceptual understanding of concern in the field of teaching AI, little is known about how these components manifest in specific situations or considerations that teachers care about and urge to address in their AI teaching practice. Accordingly, this study aimed to fill this research gap by focusing on teachers' concerns as possible responses to promote AI educational reform. Therefore, there is a need to investigate teachers' concerns about participating in the educational reform of the AI curriculum, along with identifying the factors that predict their concerns for optimizing the quality of instruction in AI education.

Among the predictive factors, teachers' knowledge has been proven to be associated with teachers' stages of concern (Hao & Lee, 2015). Specifically, Kim et al. (2021a) indicated teachers' knowledge is positively related to specific stages of their concern, while Hao and Lee (2016) mentioned that some knowledge could negatively predict teachers' specific stages of concern. This inconsistency may be attributed to the potential mediating factors between teachers' knowledge and concerns (Hao & Lee, 2017), which is an area that has remained under-researched. Furthermore, we selected teachers' perceived social good as a possible mediator in the theoretical framework for the following two reasons: (1) The mere provision of CBAM and knowledge does not guarantee successful AI teaching in the context of educational reform. The effectiveness of teaching AI is susceptible to being shaped by teachers' concerns and AI content knowledge (Lin et al., 2022; Yue et al., 2024). Hence, this study proposed merging CBAM with the pedagogical content knowledge (PCK) framework, which relates to positive beliefs and emotions in AI instruction and knowing how to teach AI, respectively. The combination of these two frameworks is beneficial for teachers in mitigating the complex challenges they face when teaching AI. (2) According to the findings of interviews with experienced AI teachers, the role of AI knowledge for social good has been noted in successful AI curriculum design (Chai et al., 2020; Lin et al., 2022). Educators have highlighted perceived social good for students' cultivation in AI education (Ayanwale et al., 2022; Chai et al., 2020). Previous studies have used various tools to measure dimensions of social good, focusing on both behavioral manifestations (e.g., prosocial actions, participation in community initiatives) and psychological constructs (e.g., ethical beliefs, social responsibility, and emotional engagement). For instance, instruments based on the Collaborative for Academic, Social, and Emotional Learning model have evaluated social and emotional competencies through dimensions such as self-awareness, social awareness, and responsible decision-making (Negru, 2023). Building on these foundations, our study operationalized "social good" in the context of AI teaching as a pedagogical belief. Social good can be defined as a philosophy and practice that positively impacts society as a whole through education or other actions in the social sphere. In the context of AI education, social good is manifested not only in the practical use of technology for teaching and learning, but also in the design of curricula and pedagogical strategies to develop students' ability to utilize AI to solve social problems. This social good is manifested in pedagogical beliefs that promote the well-being of society and foster students' social responsibility, which not only supports educational reform, but is also seen as a key factor in driving teachers'

professional development (Mor et al., 2020). However, limited research has considered its benefits for teachers' professional development. Investigating teachers' perceived social good in AI education is crucial, as it potentially aids in enhancing their practice in developing effective AI courses. Teachers' knowledge of teaching AI may predict their beliefs about using AI for social good. Besides, Baker-Doyle et al. (2018) discovered that teachers who attached greater value to social good showed increased engagement in adopting educational innovations (i.e., concerns). Thus, we assumed that teachers' perceived social good might mediate the relationship between their knowledge of teaching AI and their concern about teaching AI.

Accordingly, this study aimed to construct and empirically test a hypothesized mediation model that integrates teachers' knowledge, perceived social good, and concerns about teaching AI, in order to validate the proposed hypotheses (see Fig. 1). When teachers have a high-level of knowledge of teaching Al, they may exhibit a higher degree of perceived social good when teaching AI, leading to holding higher stages of concerns about teaching AI. Particularly, the higher degree of perceived social good teachers have, the more attention they pay to teaching AI, focusing on designing successful AI courses and showing more engagement in facing AI educational innovation. In the context of educational reform focused on teaching AI, evaluating the extent of its implementation has become even more essential. The theoretical contribution of this study lies in providing an important dimension for measuring the degree of AI curriculum implementation, offering a reliable theoretical basis and measurement tool for understanding teachers' perceptions of and attitudes toward the reform. Based on the insights derived from the proposed hypothesized model, targeted beliefs and knowledge are necessary to scaffold teachers in intuitively comprehending the complex interactions between the essential components of contextualized AI instruction, which may contribute to devising more effective plans that need to be addressed in the current K-12 AI educational reform.

Literature review

Theoretical framework and research context

To help AI teachers deeply and systematically understand the complex AI teaching process, the theoretical grounding of this study was guided by the CBAM and PCK framework, which comprises two parts: extending CBAM into the

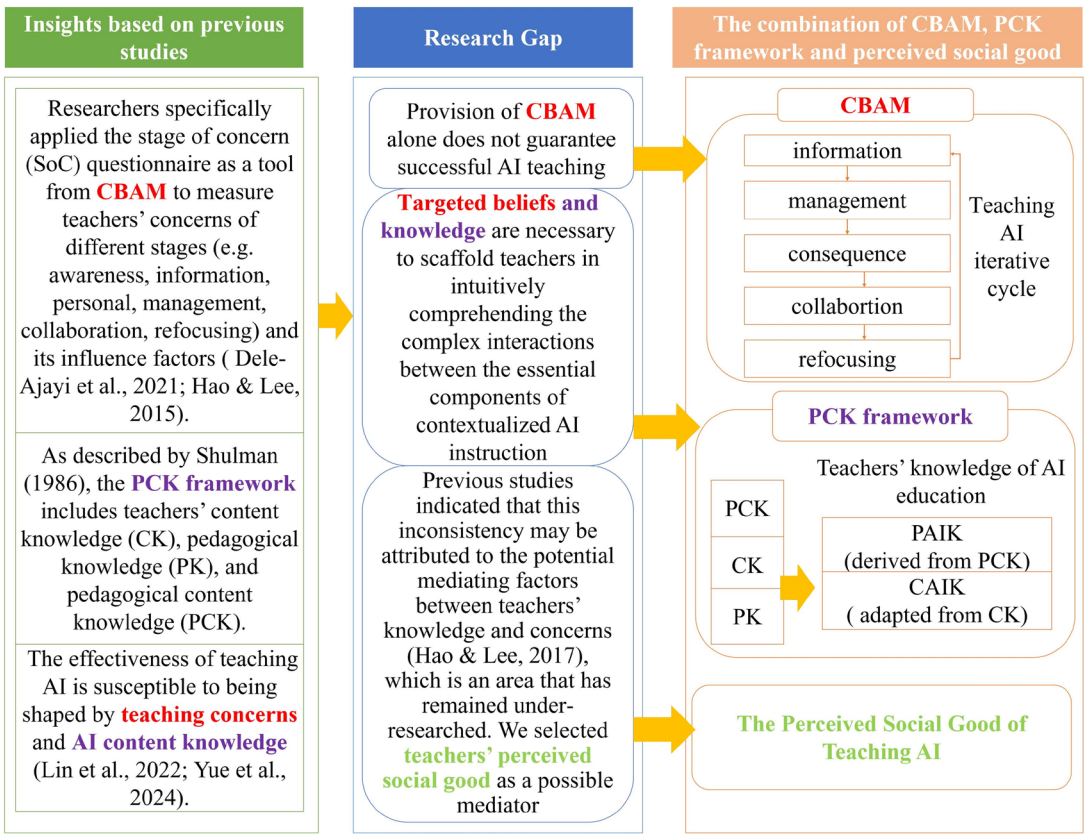

Fig. 1 Research framework

teaching AI area, and integrating PCK into CBAM for teaching AI well. The following review is structured to introduce the key factors and associated hypotheses supported by the CBAM/PCK framework and past studies.

The CBAM and AI education

An increasing number of studies have emphasized the need to focus on how teachers' emotion influences their teaching practice in the context of educational reform (Davis & Bellocchi, 2018; Weddle, 2021). This study examined teachers' concerns as hierarchical emotional responses to AI education reform and explored factors that shaped the responses. Teacher' responsive emotions in such contexts can be influenced by their personal competence, social background, and moral values (Zembylas, 2009). Teachers may develop negative emotions (e.g., fear, frustration, and resistance to such efforts) because of the imposition of unwelcome reform demands, repetition, and inconsistency of demands (Tsang & Kwong, 2017). Furthermore, teachers' negative emotions can impede AI education reform (Chen, 2019).

Since concern is a key notion of emotion, there is a growing body of research exploring components related to teachers' various concerns and their connections (Chen & Jang, 2014; Kim et al., 2021a). According to the findings of Fuller (1969), teachers' concerns change over time when facing innovations. After an educational innovation occurs, teachers' concerns have an important impact on the implementation process (Fullan, 2007; Hall & Hord, 1987). Hall et al. (1977) first designed the SoC questionnaire, one of the fundamental parts of CBAM (Cheung et al., 2001), to assess teachers' concerns when confronting an educational innovation. Researchers then applied and refined the framework to identify teachers' needs in their professional development. For example, Geng et al. (2019) refined SoC into five dimensions to assess K-12 teachers' concerns: evaluation, information, management, consequence, and refocusing. They revealed that K-12 STEM teachers' concerns were mainly concentrated on three categories: information, management, and consequence. Teachers can be provided with articulated support according to their concerns. As argued by previous research, teachers in different stages of professional development show different SoC (Al-Furaih & Al-Awidi, 2020; Byrne & Prendergast, 2020). The assessment of teachers' SoC was maintained as a vital aspect of teachers' professional development in educational innovations. After decades of continuous efforts, the CBAM framework designed by Hall and Hord (1987) has been proven to be a workable theoretical framework for understanding teachers' change process when implementing educational innovations (Al-Furaih & Al-Awidi, 2020; Lau & Jong, 2022).

CBAM has a profound influence on teachers' concerns (Dele-Ajayi et al., 2021; Hao & Lee, 2015). For instance, the SoC questionnaire was developed by Hall et al. (1977) to assess teachers' concerns about educational innovations. Many attempts have applied CBAM and SoC to examine teachers' concerns about educational reform (Byrne & Prendergast, 2020; Dele-Ajayi et al., 2021). Additionally, CBAM and SoC could be applied in modeling the changes in teachers' concerns brought by educational reforms when teachers were instructing particular subjects or technology (Kim et al., 2021a; Lau & Jong, 2022). Previous studies have explored teachers' concerns about teaching computer science. The rapid development of the use of technology has given rise to insights from researchers based on the CBAM orientated teachers' concerns about teaching computer science. There have been empirical studies focusing on teachers' concerns about teaching computer science. For instance, Kim et al. (2021a) adopted CBAM as an analytical lens to explore teachers' perceptions of and concerns about the efficacy and changes in software education, while Lau and Jong (2022) employed CBAM as a theoretical framework to explore teachers' impact-oriented concerns in STEM education.

As a central part of computer science, there is a need to use CBAM to measure and facilitate the instruction of AI. Despite the popularity of CBAM, only a limited number of studies have explored teachers' growing concerns about the educational reform brought by AI with CBAM. For example, research has employed CBAM to analyze student learning effectiveness with the purpose of improving the quality of teaching AI (Fan & Zhao, 2023). Jong (2022) applied CBAM and found that front-line teachers' concerns were mainly related to teaching AI, which propelled us to further explore teachers' concerns about teaching AI. Consequently, teachers' concerns about teaching AI are worth investigating. Given the above, this study categorized and stratified teachers' concerns about teaching AI with SoC from CBAM. We defined teachers' concerns about teaching AI as their feelings, preoccupations, thoughts, and considerations about teaching AI.

The PCK framework and AI education

To explain the crucial variables teachers are concerned about in the teaching process, previous studies integrated the variables of PCK (e.g., PK and CK) into a research model (Hao & Lee, 2017; Shin, 2021). In previous research, the TPACK framework has often emphasized the role of technology in enabling and enhancing teaching practices (Yue et al., 2021). TPACK integrates TK with PK and CK to support teachers' use of technology in instruction. In contrast, the PCK framework focuses more specifically on the interplay between pedagogy and content, emphasizing teachers' ability to employ effective instructional strategies tailored to specific subject matter (Park & Oliver, 2008; Shulman, 1986).

Studies have shown that PCK effectively captures domain-specific teaching knowledge, especially during educational reforms involving new curricula (He et al., 2021; Luft et al., 2022). Therefore, while TPACK highlights the integration of technology broadly, PCK provides a more targeted framework for addressing the unique challenges of teaching AI content. These studies indicated significant relationships between teachers' knowledge and their concerns when teachers are working with new technology (Hao & Lee, 2017). It is hoped that teachers can improve their knowledge to support appropriate concerns, resulting in their proactive competencies in educational innovations (Shin, 2021). Hence, it is imperative to pay close attention to the theories surrounding teachers' knowledge of teaching and the evolution of its related research trajectories. By doing so, we can gain a deeper understanding of how this knowledge base informs and shapes teachers' practices, particularly in the context of AI education.

Teachers' knowledge of teaching is a complex system that includes subject matter, student learning, and teaching practice (Mishra & Koehler, 2006; Shulman, 1986). Previous studies showed that teachers who teach specific subjects possess knowledge of similar types but with different connotations (Park & Oliver, 2008). Researchers have commonly applied the PCK framework to describe teachers' domain-specific knowledge, especially when innovating teachers' training for educational reform based on new curricula (Luft et al., 2022; Pringle et al., 2020). As described by Shulman (1986), the PCK framework includes teachers' content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK). PCK defines teachers' knowledge of applying effective pedagogical strategies for students' learning of specific topics. PCK has not just been applied efficiently for assessing and promoting teachers' development in teaching a specific subject (He et al., 2021; Hidayat & Setyawan, 2020). It was also modified as CS-PCK to support K-12 teachers to engage in educational reform that came along with the past new computer science (CS) curriculum (Yadav & Berges, 2019), which was applied to evaluate and promote teaching computer science (He et al., 2021; Hidayat & Setyawan, 2020). CS-PCK provides fundamental action guidance to front-line teachers (Brandes & Armoni, 2019). This guidance is significant for both novice and expert teachers (Oleson et al., 2018).

In the current K-12 educational reform brought by AI, front-line teachers are facing challenges similar to previous CS education. Their main difficulty is teaching the new AI curriculum following certain principles of practice (Kim et al., 2021b). Similar situations are found globally (Yue et al., 2021). Specifically, teachers' limited conceptual AI knowledge is mainly related to popular topics as subject matter (Lindner & Romeike, 2019). They need pedagogical tactics such as visualization, projects related to the real world, and domain specificity to teach these novel topics (Sulmont et al., 2019). Similar challenges are happening to teachers who will teach AI as well (Kim et al., 2021b). Therefore, educational research regarding teachers' consideration of teaching AI should take the PCK model into account. We thus adapted CS-PCK from teaching computer science to AI-PCK for teaching AI to identify and measure teachers' knowledge of teaching AI. This idea led to the definition of teachers' knowledge of teaching AI (AI-PCK). It refers to teachers' professional knowledge of embedding topics around AI with appropriate pedagogical strategies for efficient teaching.

The relationships among teachers' knowledge, perceived social good, and concerns about teaching AI

In this study, the relationships between teachers' knowledge, perceived social good, and concerns about teaching AI were first hypothesized based on the theoretical perspective of spaces of coping. The theory proposed by Zembylas (2006) regards teachers' emotional responses to educational reforms as being closely correlated with the social and political context. What's more, teachers' understanding of the emotional aspects of teaching and learning also shows inseparable connections with their practice knowledge (Zembylas, 2007). It was assumed that teachers' practical knowledge may be associated with their concerns as emotional responses. Accordingly, teachers need to correctly handle the relationship between teachers' knowledge and concerns as teachers are more knowledgeable when exhibiting higher SoC (Hao & Lee, 2016). However, Hao and Lee (2016) explored factors associated with teachers' concerns in flipping classrooms and found that PK, CK, and PCK may have a positive correlation with some SoC (i.e., informational, personal, management, consequence, collaboration, and refocusing), while PK, CK, and PCK were identified as being negatively related to other concerns (i.e., awareness). Accordingly, this study hypothesized that knowledge may not always serve as one positive predictor of concerns. There is a need to investigate the possible factor between knowledge and concerns to improve the accuracy and in-depth understanding of how to teach AI effectively. Between knowledge and concerns, there may be mediating variables between the two factors when teachers are facing educational innovation about technology (Hao & Lee, 2017). In light of this, potential mediators could contribute to identifying the internal mechanism between teachers' knowledge and concerns to clarify the inconsistency. At the heart of the framework lies the interplay of teachers' knowledge-PCK and CK, which links to their concerns about teaching AI.

Teachers' professional development is promoted by their knowledge improvement in teaching K-12 AI courses as well

(Kim et al., 2021b). It is reasonable to consider similarly possible mediators between teachers' knowledge and concerns about teaching AI as in previous course reform (Hao & Lee, 2017). We further proposed that teachers' perceptions of the social good of teaching AI is a crucial factor between teachers' knowledge and concerns about teaching AI because teachers who value social good have been found to perform more proactively when designing AI courses (Chiu & Chai, 2020; Lin et al., 2022).

Social good switches between social responsibility, social influence, ethics, and so on (Moore, 2019). In research, social good is similar to ethical factors of sociality and humanitarianism. These factors have been commonly reduced to social responsibility when considering the social impact of AI (Niño et al., 2017). Pedagogically, teachers who advocate social responsibility share an orientation that social good should be involved in their teaching (Serholt et al., 2017). Promoting teachers' social responsibility in teaching the use of technology has been taken as a purpose and a challenge of teacher training (Nuzzaci, 2016). Teachers who paid more attention to ethical issues of technology were found to show more engagement in facing educational innovation (Baker-Doyle et al., 2018). Furthermore, teachers concerned about social good also showed more initiative in increasing their professional knowledge and designing successful AI courses (Chiu & Chai, 2020). Based on the concept of students' perceived social good as a belief regarding using AI knowledge for solving problems and improving human lives (Chai et al., 2020), teachers' perceived social good of teaching AI refers to their pedagogical beliefs about designing AI courses that enable students to solve problems for the human value with AI.

Teachers' perceived social good as a pedagogical belief about the use of AI knowledge to solve problems and improve people's lives was selected for the following reasons: the lack of social good in teachers' pedagogical beliefs can make them lack passion in applying professional knowledge to refine AI courses and innovate effective pedagogy for AI education. Furthermore, according to the spaces of coping theory, teachers' perceived social good as an ethical factor could impact the generation of their emotional response, which is manifested as the correlation between teachers' knowledge and their concerns. It is reasonable to build intrinsic correlations with the three factors. For the analysis, SoC was applied from CBAM to measure teachers' concerns about teaching AI. Teachers' knowledge was formulated by a contextualized AI-PCK framework (i.e., PAIK in this study), which was divided into pedagogical AI knowledge, AI content knowledge, and general pedagogical knowledge.

Previous researchers have utilized the CBAM and explored how teachers' stages of concern might impact their knowledge in different contexts. Teachers' stages of concern were found to be distributed according to their knowledge level in software education (Kim et al., 2021a). The study further hypothesized that teachers' knowledge would predict their concerns about teaching AI (e.g., Path H1 in Fig. 2). Current empirical evidence suggests that teachers' concerns would be predicted by their knowledge, perceptions and experience of instruction based on the PCK framework. For example, teachers who were more equipped with work experience and pedagogical knowledge were more likely to address impact concerns and were better able to inspire student learning, thus successfully implementing STEM education (Lau & Jong, 2022; Ohlemann et al., 2023). Also, teachers' perceptions of learning and the experiences they possess are key factors in predicting their concerns about students' competence (Pellikka et al., 2024). Besides, there were unstable associations between teachers' knowledge and specific stages of concern (Hao & Lee,), implying that mediation factors might exist (Hao & Lee, 2017). Despite the previous efforts, the existing literature did not illustrate

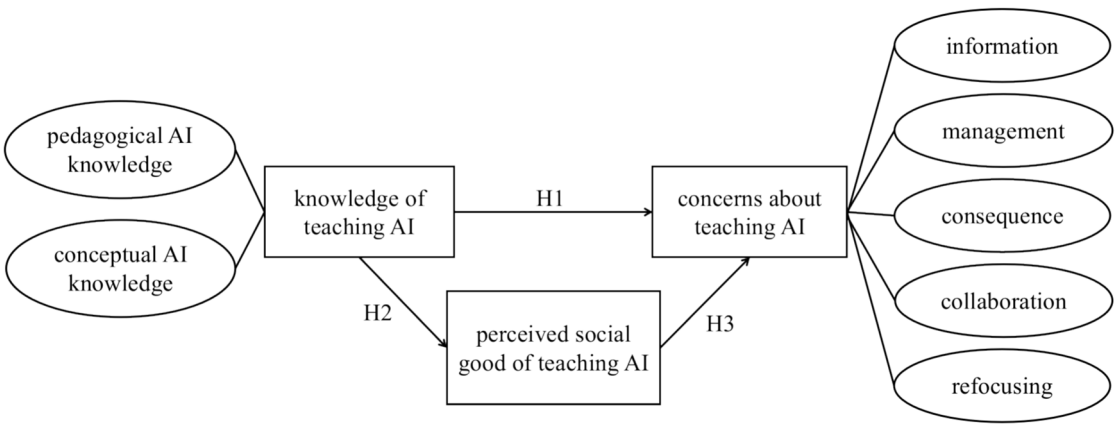

Fig. 2 Hypothesized model

the mechanisms underlying teachers' increasing knowledge and concerns in the context of K-12 AI-related educational reform.

It has been discovered that teachers' knowledge could positively impact their pedagogical beliefs (Chai et al., 2013; Luik et al., 2024). Furthermore, teachers' implementation of emphasizing social good in teaching could be facilitated when they accumulate more experience and knowledge (Lee & Choi, 2015). It is reasonable to consider that teachers' perceived social good as a pedagogical belief has a positive association with their knowledge. We accordingly hypothesized that teachers' knowledge might promote their perceived social good (see Path H2 in Fig. 2). On the other hand, teachers' pedagogical beliefs were correlated to their SoC (Kim et al., 2021a). Teachers who valued social good in their pedagogical beliefs were more likely to prioritize the consequences of students' studies (Martínez-Valdivia et al., 2020). In other words, teachers' perceived social good could facilitate their concern about higher stages in SoC, such as consequence and refocusing concern. Teachers with such concern will emphasize the potential value and harm of AI to social good in their AI courses. We thus hypothesized a positive relationship between teachers' perceived social good of teaching AI and their concerns about teaching AI (e.g., Path H3 in Fig. 2).

Thus, this study hypothesized that teachers perceived the social good of teaching AI as a mediator between their knowledge and concerns about teaching. The associations between the three factors can also be identified from a practical perspective. Teachers' concerns have shown a connection with their professional development practice for educational innovation (Chounta et al., 2022). Besides, teachers' professional development can also be promoted by their knowledge improvement in teaching K-12 AI courses (Kim et al., 2021a; Kennedy & Shiel, 2024). Teachers perceived the social good of teaching AI as a mediator between their knowledge and concerns about teaching AI because teachers who value social good performed more proactively in designing effective AI courses (Chiu & Chai, 2020). To sum up, this study built a hypothesized structural equation modeling (SEM) model (see Fig. 2) that incorporates both knowledge and social good to explain the inner and in-depth mechanisms of teachers' concerns about teaching AI.

Hypothesis development

The primary purpose of this study was to examine the relationships between teachers' knowledge of AI, their perceived social good of teaching AI, and their concerns about teaching AI. Based on theoretical frameworks and empirical studies, three hypotheses were proposed.

Teachers' knowledge of AI, including pedagogical AI knowledge and content-specific knowledge, plays a foundational role in shaping their concerns about teaching AI. Teachers with greater knowledge are more likely to effectively address instructional challenges, as knowledge influences their responses to educational reforms (Hao & Lee, 2016; Lau & Jong, 2022; Ohlemann et al., 2023). We therefore proposed the following hypothesis:

H1 Teachers' knowledge of AI positively predicts their concerns about teaching AI (see Fig. 2).

Teachers' knowledge of AI informs their pedagogical beliefs, particularly their perception of the social good achieved through teaching AI. Accumulating knowledge enables teachers to integrate ethical and societal considerations into their pedagogy (Lee & Choi, 2015). Specifically, perceived social good reflects teachers' belief in designing AI courses that help students address societal challenges and improve human lives (Chiu & Chai, 2020). Thus, the following hypothesis was proposed:

H2 Teachers' knowledge of AI positively predicts their perceived social good of teaching AI (see Fig. 2).

Perceived social good serves as an essential attitudinal factor mediating the relationship between teachers' knowledge and their concerns about teaching AI. Teachers who value the social good of teaching AI tend to focus on higher stages of concern, such as consequence and refocusing, emphasizing ethical and societal implications in their instructional design (Martínez-Valdivia et al., 2020; Serholt et al., 2017). This led to the third hypothesis:

H3 Teachers' perceived social good of teaching AI positively predicts their concerns about teaching AI (see Fig. 2).

Verification of these research hypotheses is presented later with corresponding theoretical, logical, and empirical justifications.

Research questions

The research questions posed are:

RQ1: By questionnaire analysis: Are the applied questionnaires valid and reliable for investigating teachers' knowledge, perceived social good, and concerns about teaching AI?
RQ2: By SEM analysis: What predictive roles do teachers' knowledge play in their concerns about teaching AI when mediated by the perceived social good of teaching AI?
RQ3: By supplemental interviews: What are teachers' views regarding teaching AI?

Methods

Context

China has issued several policies on teaching AI since 2017. Following the spirit of relevant national policy documents, South China has selected a batch of experimental areas and schools for the K-12 AI educational reform. Many teachers in these areas were involved in training programs for their adaptation. Due to the lack of dedicated K-12 AI courses and dedicated K-12 AI teachers in China, teachers were supported to be active innovators teaching effective AI courses after participating in the programs.

The teachers we surveyed were all involved in the AI educational reform and had experienced training programs. In the K-12 AI educational reform, part of the content of AI teaching is covered in the curriculum of information and communications technology, such as AI foundational knowledge, simple intelligent system development, development and application of AI technology, and the social good issues of AI application. Regarding social good, the newly revised textbooks of AI courses point out the goal to cultivate students' sense of social responsibility. For example, a teacher can organize students to analyze the dilemma of who should bear the responsibility caused by driverless car accidents. In this way, students' awareness of social responsibility can be enhanced, and the potential threat of AI to society can be recognized dialectically.

Participants

A total of 269K-12 AI teachers in South China were recruited (48.3% female; 51.7% male), with an average age of 33.44 (SD = 5.77). These teachers were invited because they had attended professional development programs on teaching AI and had started implementing AI courses. Their mean number of teaching years was 10.8, and their mean number of AI teaching years was 3.34. Among the teachers, 55.1% taught 10th grade, 43.9% taught 11th grade, and 1% taught 12th grade. As the front-line participants of the AI educational reform, the teachers have experience in teaching AI. They were asked to complete the online survey to evaluate the degree to which they agreed with each item. In addition, it should be noted that all teachers passed the program.

Data collection

For collecting quantitative and qualitative data, there were three steps in the data collection procedure of this study.

First, expert opinions were solicited to ensure the accuracy and credibility of the measurements related to teachers' knowledge of teaching AI, the perceived social good of teaching AI, and concerns about teaching AI. Three experts specializing in AI education reviewed the initial measurements. The experts noted that while the TPACK framework is commonly used to study technology integration in subject teaching, it is less applicable for teaching AI as a standalone subject. They recommended adopting the PCK framework, which better aligns with the focus on integrating pedagogy and content for teaching technical knowledge. Based on the recommendations of the experts, the wording and scale items were modified and revised.

Second, a pretest was conducted to refine the questionnaire. The results showed that general AI teachers found it challenging to distinguish the multiple dimensions of TPACK. In contrast, they could clearly identify elements of PCK, particularly in the context of teaching AI. Thus, the final questionnaire adopted the PCK framework. Trained research assistants distributed and collected questionnaires using an online questionnaire publishing platform. The questionnaire data collection lasted about 6 months (October 2020 to March 2021). The survey was anonymous and could be completed within 20 min.

Third, after the questionnaire survey, semi-structured interviews were conducted for this study in order to gain insights into the teachers' experiences of teaching AI in a supplementary manner. The interview data collection lasted almost 1 year (October 2020 to September 2021). Each teacher was asked to participate in interviews to gather teachers' knowledge, perceived social good of teaching AI, and their roles in teaching concerns about teaching AI. Each interview lasted approximately 20 min and was audio-recorded and transcribed verbatim for data analysis.

Instruments

Knowledge of teaching AI

The Knowledge of the teaching AI subscale was adapted and modified from the scale of Chai et al.'s (2013) study. The original subscale surveyed participants' teaching knowledge, including PCK, CK, and PK. Cronbach's alpha of PCK, CK, and PK in the work of Chai et al. (2013) was 0.92, 0.88, and 0.90, respectively. Based on the framework, we developed our subscale to test teachers' knowledge of AI education as pedagogical AI knowledge (PAIK, which is derived from PCK), and conceptual AI knowledge (CAIK, which is adapted from CK). To accommodate the subscale to the context of the study, 13 items were referenced, of which eight were for PAIK, and five were for CAIK. All items were rated on a 6-point Likert scale from 6 (*strongly agree*) to 1 (*strongly disagree*). The two dimensions are as follows:

PAIK measures teachers' knowledge of what, when, why, and how to teach AI (e.g., 'I can design exploration activities to help students understand the knowledge of AI').

CAIK refers to conceptual AI knowledge about AI-specific software or hardware (e.g., 'I have enough relevant knowledge about the intelligent robots.').

Perceived social good of teaching AI

The Perceived Social Good of Teaching AI subscale was modified from the scale of Chai et al. (2020). Only three of the five original items by Chai et al. (2020) were retained for further analysis in this study. The Cronbach's α of social good in the original survey was 0.82, and CR was 0.82. This part contained three items and showed high reliability. Responses were anchored on a 6-point Likert scale from 6 (*strongly agree*) to 1 (*strongly disagree*). The dimension of social good of teaching AI aimed to measure teachers' pedagogical beliefs that designing AI courses enables students to solve problems using AI for the benefit of humans (e.g., I believe that teaching AI can encourage students to design AI applications for the good of society).

Concerns of teaching AI

The subscale of Concerns about teaching AI was designed based on the SoC instruments of Hall et al. (1977) and Geng et al. (2019). The subscale includes five stages: information (5 items), management, consequence, collaboration, and refocusing. Of these stages, the current research only adopted the subscale of management and refocusing due to its stronger associations with teachers' teaching innovative content (Jong, 2019). We made this decision also based on the psychometric properties of the management and refocusing subscales. Both the correlation between the management dimension and the total scale ($r = 0.82$, $p < 0.001$) and the correlation between the refocusing dimension and the total scale ($r = 0.81$, $p < 0.001$) were higher than that between the information dimension and the total scale ($r = 0.49$, $p < 0.001$), between the consequence dimension and the total scale ($r = 0.48$, $p < 0.001$), as well as between the collaboration dimension and the total scale ($r = 0.56$, $p < 0.001$). Participant responses were measured with a 6-point Likert-type scale (1 = *strongly disagree*, 6 = *strongly agree*). The two dimensions are described as follows:

Management refers to teachers' concerns about organizing, managing, and scheduling the instructional activities to implement the AI curriculum smoothly (4 items).

Refocusing measures teachers' concerns about further developing and improving the existing pedagogical effectiveness of the AI courses (7 items).

Data analysis

Two steps were applied to analyze the data, including the confirmatory factor analysis (CFA) and SEM analysis. CFA was conducted to assess the reliability and validity of the questionnaires and to evaluate the measurement model. SEM was estimated to verify the hypothesized relationships between teachers' knowledge, concerns, and perceived social good of teaching AI. All analysis was conducted with SPSS 22.0 and Mplus 8.2. The Cronbach's α and composite reliability (CR) were applied to confirm the high consistency of each construct; Hair et al. (2009) suggested that CR and Cronbach's α should both exceed 0.7. Then, the average variance extracted (AVE) was computed to confirm the discriminant validity of the survey. The AVE value of each construct should be greater than 0.5, and the square root of AVE should exceed the correlation coefficients between that construct and other structures to ascertain that the constructs are independent of each other (Hair et al., 2009). Third, the Tucker-Lewis index (TLI), comparative fit index (CFI), and standardized root mean square residuals (SRMR) were reported as the model fitness. Based on Marsh et al. (2004), a CFI of at least 0.90, a TLI of at least 0.90, and an SRMR < 0.08 together would suggest a good fit between the hypothesized model and the data.

Semi-structured interviews

To gain deeper insights into teachers' experience with teaching AI, this study conducted supplemental semi-structured interviews. The interviews aimed to explore teachers' knowledge, perceived social good of teaching AI, and their roles in teaching concerns about teaching AI, with the aim of further supplementing the quantitative findings by analyzing relevant data sources (i.e., self-reported survey and interview). Among the 269 survey participants, we invited 18 teachers (9 males and 9 females) to take part in the supplemental interviews. The teachers were selected based on their different levels of proficiency in implementing AI courses in professional development programs (6 teachers with high-level, 6 with medium-level, and 6 with low-level proficiency). Example interview questions included: (1)'When were you a participant in the reform of teaching AI? and What do you think of this reform?' (2) 'What issues were you largely concerned about during the reform of teaching AI, and Why?' (3)'What is your favorite part of teaching AI, and what is your least favorite part?' (4)'What made you find it difficult or challenging to conduct the AI teaching?' (5)'Can you specifically describe any changes in your feelings during that period?'.

Results

Validity and reliability of the instruments

To answer RQ1, CFA was applied to validate the factorial structure of each scale, and the coefficient alpha was used to test the reliability of all the scales. Parceling was employed for the sake of model estimation benefits in the CFA and SEM phases (Little et al., 2013). The parceling strategy for PAIK and CAIK was a factorial algorithm (Rogers & Schmitt, 2004), while refocusing adopted prior questionnaire construction (Little et al., 2002).

CFA for knowledge of teaching AI

Only two dimensions that comprise 13 items were retained for the subscale. The measurement model of the knowledge of teaching AI subscale is presented in Table 1. The items consist of two factors (PAIK and CAIK) with 13 items. The dimension of general pedagogical knowledge was deleted due to its factor loading being less than 0.40.

In this study, the Cronbach's α values of PAIK and CAIK were 0.97 and 0.89, with an overall alpha of 0.95, showing that this instrument is reliable. The examination of the CR of each construct showed that it was greater than 0.70, and the AVE of each construct exceeded the value of 0.50: PAIK (CR = 0.97, AVE = 0.76), CAIK (CR = 0.89, AVE = 0.62).

CFA for the perceived social good of teaching AI

As noted in Table 1, the measurement model of the perceived social good of teaching AI subscale included three items. In the study, the Cronbach's α value of the perceived social good scale was 0.93, and the CR and AVE values of the scale were 0.93 and 0.81, suggesting that this scale is reliable and effective.

CFA for concerns of teaching AI

The measurement model of concerns of teaching AI subscale consists of two factors (Management and Refocusing) with 11 items, as shown in Table 1. Other dimensions were deleted due to their factor loadings being less than 0.40. Cronbach's alpha values were 0.92 for Management and 0.89 for Refocusing, and the overall alpha value was 0.90, indicating sufficient internal consistency of the survey items. The CR and AVE values of the scale further confirmed its reliability: management (CR = 0.92, AVE = 0.73), and refocusing (CR = 0.90, AVE = 0.55).

Description and correlation analysis

Responding to RQ2 regarding the SEM analysis, sequential steps were conducted in the following two subsections: (1) correlation analysis to explore the relations among teachers' knowledge, perceived social good, and concerns about teaching AI, and (2) mediation effect testing to reveal the mediator role of teachers' perceived social good of teaching AI between their knowledge and concerns about teaching AI.

In the first step to explore the relations, the results of the descriptive statistics and Pearson correlation analyses of all constructs are shown in Table 2. The AVE of each construct exceeded the value of 0.50. The square roots of the AVE of each construct were greater than the Pearson correlation coefficients for each pair of constructs, resulting in the survey's great reliability and validity. The fit indices for the five constructs after parceling were $\chi^2/df = 3.44$, CFI = 0.97, TLI = 0.96, and SRMR = 0.04, indicating that the survey items had acceptable construct validity.

The mean score of each construct was between 4.33 and 4.73 (*SD* between 0.61 and 1.09), suggesting that participants were well-trained for AI education. All of the correlation coefficients were positive and significant ($p < 0.001$), and were between 0.40 and 0.78, showing medium to large effect size coefficients.

Analysis of mediating effects

Latent variables modeling was used for mediation effect testing, and the estimated standardized path coefficients are presented in Fig. 3 and Tables 3 and 4. Parceling strategies used in SEM were identical to the CFA analysis.

We examined the mediating effect with a two-step procedure. The total effect was estimated first. Without controlling the perceived social good of teaching AI, CAIK predicted management significantly ($\beta = 0.39$, $p < 0.001$), while PAIK could not predict management ($\beta = 0.14$, $p = 0.109$). The total paths from both CAIK ($\beta = 0.16$, $p < 0.05$) and PAIK of teaching AI ($\beta = 0.57$, $p < 0.001$) to refocusing were found to be significant.

Second, the mediation effect was tested. Both CAIK ($\beta = 0.39$, $p < 0.001$) and the perceived social good of teaching AI ($\beta = 0.37$, $p < 0.001$) predicted management significantly, suggesting the mediator role of the perceived social good of teaching AI. The mediation effect of management on CAIK via the perceived social good of teaching AI was significant ($\beta = 0.14$, $p < 0.001$), accounting for 37% of the total effect. After controlling the perceived social good of teaching AI, CAIK still significantly predicted management ($\beta = 0.25$, $p < 0.01$). Therefore, the perceived social good of teaching AI partially mediated the relationship between CAIK and management. The mediation effect was not estimated for PAIK on management. Thus, it could not predict

Table 1 Factor loadings and the reliability of the knowledge of teaching AI subscale

Items	Factor loadings	*t*-value	AVE	CR	Cronbach's α
Factor 1—Pedagogical AI knowledge (PAIK)			0.76	0.97	0.97
PAIK1—I can inspire students to brainstorm and discover the potential benefits of AI technology	0.85	46.90***			
PAIK2—I can guide students to use intelligent images to design appropriate solutions	0.85	46.46***			
PAIK3—I can help students choose the suitable machine learning algorithm needed for a given problem	0.89	65.69***			
PAIK4—I can design interesting teaching activities to help students use automatic speech recognition well	0.88	59.18***			
PAIK5—I am able to incorporate AI software (such as Siri or face recognition) into students' learning activities	0.90	71.41***			
PAIK6—I can raise questions from the real world to inspire students to learn artificial intelligence	0.89	61.90***			
PAIK7—I can lead students to argue about AI technology issues	0.87	51.96***			
PAIK8—I can design exploration activities to help students understand the knowledge of AI	0.87	53.61***			
Factor 2—Conceptual AI knowledge (CAIK)			0.62	0.89	0.89
CAIK1—I have enough relevant knowledge about cloud computing	0.90	55.30***			
CAIK2—I have enough relevant knowledge about computer vision	0.88	47.03***			
CAIK3—I have enough relevant knowledge about deep learning	0.69	18.73***			
CAIK4—I have enough relevant knowledge about knowledge graphs	0.79	29.89***			
CAIK5—I have enough relevant knowledge about intelligent robots	0.67	18.22***			
Factor 3—Social good (SG)			0.81	0.93	0.93
SG1—I believe that teaching AI can encourage students to construct ideas for using AI technology to generate social benefits	0.91	66.17***			
SG2—I believe that teaching AI can encourage students to generate ideas for the development of AI technology that benefit most people	0.95	85.52***			
SG3—I believe that teaching AI can encourage students to design AI applications for the good of society	0.85	44.31***			
Factor 4—Management (MT)			0.73	0.92	0.92
MT1—I am concerned that there are not enough class hours to organize my AI curriculum every day	0.88	52.00***			
MT2—I am concerned that I would be unable to manage key processes in teaching AI courses	0.92	65.36***			
MT3—I am concerned about the time I need to spend dealing with subject issues related to AI technology	0.86	45.19***			
MT4—I am concerned about whether there are not enough resources to teach AI courses	0.77	27.66***			
Factor 5—Refocusing (RS)			0.55	0.90	0.89
RS1—I am concerned about establishing partnerships with other teachers in and out of school to implement new AI courses	0.53	11.39***			
RS2—I am concerned about coordinating with others to maximize the impact of AI education	0.70	20.71***			
RS3—I am concerned about working with researchers to design AI courses to promote students' learning of AI	0.83	37.21***			
RS4—I am concerned about using students' feedback to improve the AI curriculum	0.77	27.51***			
RS5—I am concerned about changing the teaching methods of the AI curriculum	0.90	58.93***			
RS6—I am concerned about optimizing our AI curriculum based on students' experience	0.88	49.84***			
RS7—I am concerned about revising the AI course until it works well enough	0.67	18.46***			

***$p < 0.001$

Table 2 Correlation and discriminant validity of constructs

Factors	*M*	*SD*	AVE	1	2	3	4	5
PAIK	4.73	0.94	0.76	**0.87**				
CAIK	4.34	1.01	0.62	0.78 ***	**0.79**			
Management	4.33	1.09	0.73	0.43***	0.48***	**0.86**		
Refocusing	4.39	0.61	0.55	0.66***	0.53***	0.40***	**0.74**	
Social good	4.42	1.05	0.81	0.67***	0.67***	0.54***	0.46***	**0.90**

AVE, average variance extracted; CAIK, Content Knowledge about AI; PAIK, Pedagogical AI Knowledge. The square root of the AVE value is in bold on the diagonal. Off diagonal values are the Pearson correlations of the constructs

***$p < 0.001$

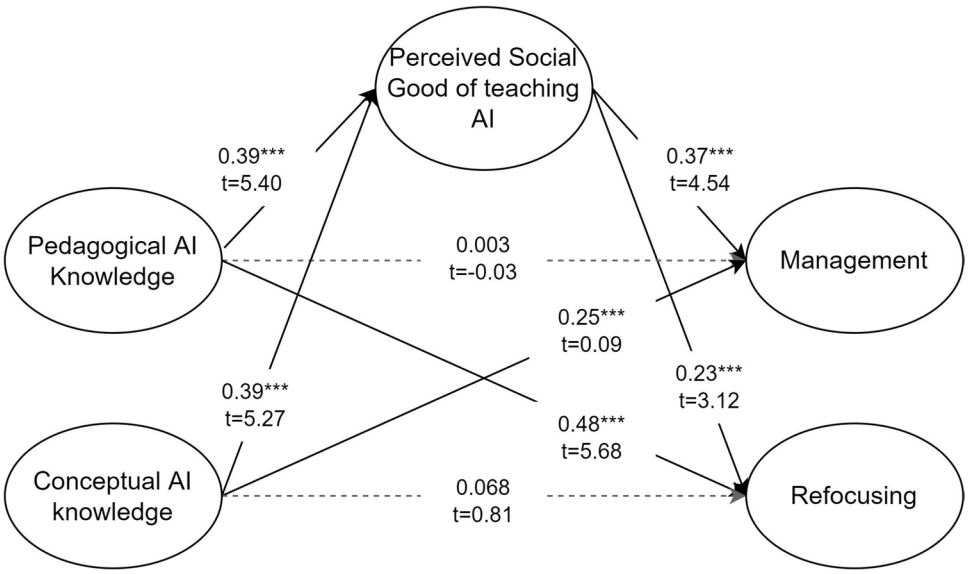

Fig. 3 Standardized results of the structural model equation. *Note* **$p < 0.01$; ***$p < 0.001$

Table 3 Mediation effect of Social Good between knowledge and management

	Y: Management		M: Social good		Y: Management			
	Path coefficient	*t*-value	Path coefficient	*t*-value	Path coefficient	*t*-value	Mediation effect (ab)	*t*-value
X: PAIK	0.142	1.603	0.391	5.404***	−0.003	−0.029	–	–
M: Social good	–	–	–	–	0.371	4.537***		
X: CAIK	0.394	4.522***	0.389	5.274***	0.25	2.726**	0.144	3.473***
M: Social good	–	–	–	–	0.371	4.537***		

CAIK: content knowledge about AI; PAIK: pedagogical AI knowledge

**$p < 0.01$; ***$p < 0.001$

management by itself, while PAIK significantly predicted the perceived social good of teaching AI ($\beta = 0.39$, $p < 0.001$), and the perceived social good of teaching AI significantly predicted management.

Further, we tested the mediating effect of perceived social good of teaching AI between the relationship of knowledge and refocusing. The path coefficients from both CAIK to the perceived social good of teaching AI ($\beta = 0.39$, $p < 0.001$) and from the perceived social good of teaching AI to refocus were found to be significant ($\beta = 0.23$, $p < 0.01$). The mediation effect of refocusing on CAIK via the perceived social good of teaching AI was significant ($\beta = 0.09$, $p < 0.001$), accounting for 57% of the total effect. After controlling the perceived social good of teaching AI, the direct effect between CAIK and refocusing disappeared ($\beta = 0.07$, $p = 0.42$).

Table 4 Mediation effect of Social Good between knowledge and refocusing

	Y: Refocusing		M: Social good		Y: Refocusing			
	PC	*t*-value	PC	*t*-value	PC	*t*-value	Mediation effect (ab)	*t*-value
X: PAIK	0.57	7.24***	0.39	5.40***	0.48	5.68***	0.09	2.72**
M: Social good	–	–	–	–	0.23	3.12**		
X: CAIK	0.16	1.98*	0.39	5.27***	0.07	0.81	0.09	2.66**
M: Social good	–	–	–	–	0.23	3.12**		

CAIK, conceptual AI knowledge; PAIK, pedagogical AI knowledge; PC, path coefficient

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

As for the mediating effect of social good between PAIK and refocusing, the path coefficients from both PAIK to the perceived social good of teaching AI ($\beta = 0.39$, $p < 0.001$) and from the perceived social good of teaching AI to refocus were significant. The perceived social good of teaching AI mediated the relationship between refocusing and PAIK ($\beta = 0.10$, $p < 0.01$), accounting for 16% of the total effect. After controlling the perceived social good of teaching AI, PAIK still predicted refocusing ($\beta = 0.48$, $p < 0.001$). Three mediation models in total were constructed from the results.

Interview analysis

To complement the findings of the SEM, this study revealed the teachers' concerns about teaching AI with empirical data from interviews, thus responding to RQ3. The interview analysis results are listed in Table 5, which focuses on the possible explaining factors of teachers' views on teaching AI, including teachers' knowledge, their concerns, and their perceived social good of teaching AI. We conducted 18 sample supplemental interviews. Regarding the role of teachers' knowledge of teaching AI and perceived social good of teaching AI, the interviews indicated that teachers with more favorable levels of social good of teaching AI were predicted by higher degrees of perceived technology-assisted teacher support, which may explain why they perceived higher levels of SoC. For example, the 2.2 (i.e. refocusing on AI classroom improvement) result showed that the teachers were quite concerned about the effectiveness of AI classrooms and felt a sense of satisfaction because they experienced social empowerment, and a spirit of inquiry and enthusiasm for teaching the students to make good use of AI for social benefits (i.e. 3.0).

They paid more attention to pedagogical knowledge of teaching AI before conducting AI courses, which was considered by other teachers and supervisors as their competence regarding the 'experience–experiment–application' approach for AI projects (i.e. pedagogical knowledge of teaching AI). This evidence from the interviews suggests that the role of perceived social good of teaching AI is a critical factor in effectively organizing AI classes (see more interview examples in Table 5).

Discussion

This study explored the direct effects of teachers' knowledge and perceived social good of teaching AI on their concerns about teaching AI, as well as the mediating role of teachers' perceived social good of teaching AI between their knowledge and concerns by adopting SEM analysis. In response to RQ1, data analysis indicated that reliable conclusions were drawn from the applied questionnaires. For RQ2, the results of the SEM analysis revealed that teachers' perceived social good of teaching AI played a significant mediating role between teachers' knowledge and their concerns about teaching AI. As a response to RQ3, teachers' understanding regarding teaching AI was revealed by the interview analysis to complement the SEM findings with empirical data.

Compared with previous studies, which only noted the importance of applying CBAM to measure teachers' concerns in conventional teaching contexts (Dele-Ajayi et al., 2021; Yan & Deng, 2018), one of the uniqueness of this study is to enrich the application of CBAM and PCK with modeling and import them to study the K-12 educational reform brought about by AI. It was found that teachers' knowledge of teaching AI was positively associated with their concerns about teaching AI. This result agreed with the previous finding, suggesting a positive correlation between teachers' knowledge and hierarchical concerns (Hao & Lee, 2016). This study further supported this idea in the context of teaching AI. It also indicated the validity of the spaces of coping theory and extended the research on teachers' emotions regarding educational reform. Based on the theoretical framework of spaces of coping, teachers respond to the practice of educational reform in terms of awareness, reflection, feeling, and connection (Zembylas, 2006). This supports the applicability of using the spaces of coping framework as an alternative framework for addressing teacher concerns in AI education. Furthermore, our results support a different conclusion and surpass past research by including the

Table 5 Categories of teachers' views regarding teaching AI

Conceptions	Values	Examples
1. Knowledge of Teaching AI	1.1 Pedagogical knowledge of the 'experience–experiment–application' approach for teaching AI	1.1.1 I used an application called CocoBlockly (a programming development environment based on Blockly visual programming blocks) to provide the students with AI-related learning experience. I could give the students a headset with a manufactured microphone to speak in an experiment. And then, the application could convert their voice into text
		1.1.2 I used graphical programming software to help students develop basic AI applications through guided experiments. This approach improved their self-confidence and problem-solving skills
	1.2 Knowledge of AI-related conceptual understanding	1.2.1 The topic of this class is related to the knowledge regarding face recognition, which is one of the technologies in artificial intelligence technology
		1.2.2 I explained the concept of neural networks by using real-life analogies, like how the human brain processes visual information. This helped students better understand the complex mechanisms of AI
2. Concerns of Teaching AI	2.1 Classroom management regarding time	2.1.1 I am largely concerned about not having enough time to organize the AI teaching classroom because the class time was so short and there were dozens of students' AI projects that needed to be evaluated
		2.1.2 I found the time constraints made it challenging to ensure students fully understood each AI topic before moving on to the next one
	2.2 Refocusing on AI classroom improvement	2.2.1 I am rather concerned about the idea of improving AI classes based on project-based learning methods. I spent a lot of time trying suitable teaching reform strategies
		2.2.2 I incorporated collaborative projects, which was beneficial, but managing group dynamics and ensuring that all students contributed equally posed significant challenges, requiring additional classroom strategies
3. Perceived Social Good of Teaching AI	3.1 Societal contribution	3.1.1 I think we need to teach AI for our children to make good use of it for social benefits
		3.1.2 I believe that by teaching AI, students can develop skills to benefit society, which motivates them to contribute positively to their communities
	3.2 Positive impact on the environment	3.2.1 I have seen students show enthusiasm when using AI for environmental projects, such as predicting pollution trends through data analysis tools. This reinforced my belief in AI's potential for positive social impact

perceived social good of teaching AI in the mediational mechanism between teachers' knowledge and concerns. In contrast to the previous finding that some domains of teachers' knowledge might be negatively associated with their concerns (Hao & Lee, 2016), teachers' perceived social good was confirmed to be an effective mediator between the two factors in the new context. The connotation is consistent with several past studies as well. Teachers' knowledge of ethics was positively associated with their attitude to technology (Yildiz Durak, 2021), and teachers' attitudes could positively predict their concerns (Kim et al., 2021a). In line with these, teachers' knowledge could affect their perceived

social good of teaching AI. When teachers not only took AI as a tool but considered the social impact of AI in their course design as well, they could show more autonomy in applying their knowledge to teaching AI courses (Chiu & Chai, 2020). Therefore, teachers' enthusiasm for implementing practice could be engaged to develop high stages of concern (Christesen & Turner, 2014). Consequently, teachers with different levels of perceived social good demonstrate corresponding concerns. This may provide a theoretical insight into the inconsistency by explaining whether teachers' knowledge can enhance or reduce their concerns in the context of teaching AI.

Furthermore, the most novel aspect of this study is the use of the mediation model to afford a meticulous explanation of the mechanism behind teachers' professional development for teaching AI courses. The mechanism discusses the shift in teachers' focus from acquiring knowledge to the direction of their specialization. Specifically, experienced teachers and novice teachers follow different professional development paths; the difference lies in their knowledge of teaching AI and their concerns about teaching AI with the mediation role of the social good of teaching AI. First, the perceived social good in teaching AI partially mediates the association between CAIK and concern about management. Second, PAIK did not positively predict concern about management, but it did positively predict the perceived social good of teaching AI, and in turn, it positively predicted concern about management. In general, teachers' perceived social good of teaching AI mediates the association between teachers' knowledge and their concern about management. The result responded to a past study, which suggested an unstable correlation between knowledge and concern about management (Hao & Lee, 2017). It proved that teachers' perceived social good of teaching AI might be one of the variables determining whether the relationship between teachers' knowledge and concern about management is positive or negative. As we hypothesized, perceived social good as a pedagogical belief can affect teachers' practice in applying knowledge of teaching AI. According to Chiu and Chai (2020), perceived social good plays an important role in predicting whether teachers can design effective AI courses. It also appears that teachers attach slightly higher importance to social topics than pure application-oriented competencies when teaching AI (Lindner & Romeike, 2019). Apart from the above, other results noted how teachers' knowledge predicts their concern about refocusing. Teachers' perceived social good of teaching AI has a full mediation effect on the association between CAIK and concerns about refocusing. Besides, teachers' perceived social good of teaching AI partially mediated the association between PAIK and concerns about refocusing. The correlations elucidated the conclusion that teachers' professional development is a process with gradually increasing social responsibility (May & Curtner-Smith, 2021). The sociocultural expectancy internalized by teachers can drive them to innovate effective pedagogy for teaching AI courses (Chiu & Chai, 2020).

However, according to the proposed model, teachers' general pedagogical knowledge has no significant effects on teachers' perceived social good or concerns about teaching AI. The result agreed with the opinion that teachers need a paradigm shift in their pedagogy for teaching AI (Tedre et al., 2021). In addition, teachers' information, consequence, and collaboration concerns about teaching AI showed insignificant connections with their knowledge and perceived social good of teaching AI. This result complemented the previous conclusion that teachers' perspectives on teaching AI emphasized teaching new courses with adequate teaching material and best-practice examples (Lindner & Romeike, 2019). It seems that teachers did not give priority to information collection, students' experience, or partnership at the beginning of the educational reform brought by AI. Instead, they concentrated on adapting the new AI courses first.

Taken together, the interview analysis shows that high-level proficient teachers possess a higher level of knowledge in teaching AI (e.g., PAIK), which mainly results from eliciting a sense of teaching AI for the benefit of humans (one characteristic of perceived social good of teaching AI) with immediate and sustained action in their concerns about teaching AI. The medium-level and low-level proficient teachers perceived more conceptual AI knowledge in their knowledge structure, and gradually increased their perception of the social good of teaching AI for autonomy in managing AI instruction. In other words, PAIK may elicit a gap between the initial value and resulting actions, which may promote immediate and sustained action (e.g., In a typical semester with 20 information technology lessons, AI courses constitute only 40% of the total, highlighting the limited allocation of time for teaching AI content. This limitation requires that teaching strategies incorporate the PAIK, which focuses on teachers' knowledge of the what, when, why, and how of teaching AI), and in turn alleviate teachers' concerns. CAIK boosts teachers' perception of the social good of teaching AI through satisfying autonomy needs in management, in turn resulting in an increase in teachers' concerns (e.g., When teachers tend to hold a higher level of CAIK, a greater extent of perceiving social good in AI teaching advances their concerns from classroom management to refocusing on teaching AI). The evidence from the interviews suggests that the role of perceived social good in teaching AI is a critical factor in mediating the relations between knowledge of teaching AI and teachers' concerns.

Conclusions, implications, and limitations

The study has provided initial evidence to reveal that teachers' perceived social good serves as an important pathway from their knowledge to their concerns in the context of the educational reform brought by AI. Impressively, teachers' perceived social good of teaching AI partially mediated the relationships between their PAIK and refocusing concerns, as well as between their CAIK and management concerns.

To fill this gap in the literature, this study broadened the application of CBAM to the field of teaching AI to deepen our understanding of teachers' knowledge and concerns by considering the mediating role of perceived social good regarding teaching AI. In other words, the main theoretical contribution of this study is that it develops the research on teachers' emotions about AI educational reform by focusing on teachers' concerns and exploring the influencing factors. The study provides evidence that CBAM can regarded as the theoretical underpinnings to help relevant stakeholders understand the mechanism underlying teachers' concerns about teaching AI. Secondly, this study used SoC from CBAM to analyze teachers' concerns, and linked it with the PCK to explore and clarify a possible explanation of the association between teachers' knowledge and concerns about teaching AI. By applying PCK to a new subject, the proposed model also shows a mechanism behind teachers' in-service professional development for teaching AI courses. In response to the current foci on challenges brought by AI education (Kim et al., 2021a), the research provides theoretical support to structuring teachers' knowledge growth and its influence on their concerns about the education reform brought by AI. A more significant finding is that teachers' perceived social good appears to be an influential factor in the process of their knowledge growth. Teachers' development of the stage of concern is not spontaneous during the teaching AI process, which requires foster promoters (e.g., knowledge and social good) to awaken and support the development of teachers' concerns through effective intervention.

From a practical perspective, to address the competency requirements and ethical challenges teachers encounter in the new AI educational reform (Akgun & Greenhow, 2022), educators must provide support to training first-line teachers and consider their concerns (Jiang, 2022). This study might help to identify the priorities and formats of designing appropriate professional development programs for teachers confronting AI educational reform. The findings indicate the significance of separating different strategies for novice and experienced teachers in their professional development programs. Directional planning could be prepared for different teachers to help them achieve high-stage concerns. For novice teachers who lack CAIK (Lindner & Berges, 2020), the results introduce the perceived social good of teaching AI to understand how their CAIK predicts their concerns about management. Novice teachers' education programs should support their development with curriculums that teach both ethical and technical concepts of AI in order to increase their CAIK. These teachers hoped to comprehend basic conceptual AI knowledge with tools like platforms using AI techniques as well as ethical matrices (Williams et al., 2021). For experienced teachers who need PAIK (Sanusi et al., 2022), the mechanism revealed by the mediation model implied the pivotal role of teachers' perceived social good in the association between their PAIK and concern about refocusing. Programs promoting experienced teachers' perceived social good are essential for their professional development. Specifically, these teachers need to create lesson plans with contextualized resources and to critically rethink the sustainable development of using AI, thus developing their PAIK. It is suggested that program designers emphasize hands-on activities and co-design training for them (Sanusi et al., 2022).

Based on these practice-oriented insights, we provide recommendations for practitioners to enhance teachers' beliefs about teaching and learning, as well as their effectiveness in using AI instructional technologies.

First, teachers should actively engage in professional development focused on AI concepts and pedagogical strategies specific to AI education. Participation in targeted training helps teachers develop a thorough understanding of AI content, acquire effective methods to teach complex AI topics, and gain practical experience in conveying these concepts in the classroom. Applying this knowledge directly to classroom practice through the design of AI-related projects, competitions, or problem-solving activities can further improve their instructional effectiveness and reduce their concerns regarding teaching AI. Additionally, maintaining curiosity about advancements in AI and continuously updating their subject-specific knowledge is crucial to meeting the demands of AI education.

Second, school leaders are encouraged to organize supportive AI education communities involving teachers, AI experts, and subject leaders. These communities facilitate collaboration, enabling teachers to share experiences, learn from experts, and experiment with new approaches to AI education. Establishing these communities fosters an environment that enhances teachers' literacy in teaching AI. School leaders should also allocate sufficient resources and structured time for professional development and collaboration within these communities, ensuring effective implementation of AI education.

Third, policymakers are expected to develop and implement specialized training programs to enhance teachers'

competencies in teaching AI. These programs should be guided by AI experts, emphasizing the broader social good of AI education to address teachers' concerns and foster motivation. Additionally, efforts should focus on ensuring the successful rollout of these training programs across schools, providing teachers with the necessary support to teach AI effectively.

However, there are some limitations to consider in the future. First, the scale of knowledge of teaching AI, perceived social good of teaching AI and concerns of teaching AI used for the objective measurement may have significant limitations due to the fact that self-reporting by participants may introduce biased results. In light of this, semi-structured interviews could be used as a tool to reduce biases by conducting in-depth interviews about the relevant self-report questions in the scales. Additionally, the SEM approach used in this study may have inherent limitations, including potential biases related to model assumptions and data relationships, which could affect the reliability of the results. Future research could enhance the systematization of variables in the model, particularly regarding the knowledge teachers need for effective AI instruction. While this study did not explore the use of generative AI (GenAI), such technologies are emerging as promising tools for AI education. For instance, GenAI could facilitate interactions where students express their ideas about AI-related topics, generating data that complement traditional survey methods. Future studies could consider incorporating these practices to better capture the evolving needs and directions of AI teaching. Furthermore, continuous observation could be used to evaluate the long-term impact of interventions and validate the mechanisms identified in this study. Second, although this study identified the mediating role of teachers' perceived social good, there may be other important relationships between different aspects of teachers' knowledge and concerns about teaching AI. Modified models with knowledge and concerns categorized by new frameworks and altered perceived social good can be further explored with data collected in other circumstances. Models from different aspects may obtain a more comprehensive understanding of teachers' professional development for AI educational reform. Third, the effectiveness of the model requires future practice. We also suggest that future studies incorporate social good into the content of teacher education programs for teaching new AI courses by designing directed activities for novice and experienced teachers. The mechanisms illustrated by the model can be further tested after identifying whether the intervention designed to improve teachers' perceived social good can differentiate their concerns.

Besides, another limitation of this study is its focus on teachers from southern China, which may restrict the generalizability of the findings. Regarding cultural factors, the significant academic competition in East Asia influences teachers' concerns, particularly via the widespread emphasis on examination outcomes. The prevalence of extracurricular tutoring in this context also drives teachers to focus on the tangible, practical benefits of teaching AI, aligning with the societal expectations for student success. In terms of systemic factors, several aspects of the educational environment affect teachers' concerns. First, the focus on examination performance impacts decisions about the duration and depth of AI courses, as priority is often given to subjects that directly contribute to exam results. Second, the availability of suitable instructional resources, including AI teaching materials and tools, influences how effectively AI can be taught. Lastly, teacher and student AI literacy remains a critical factor, as limited knowledge of AI concepts can heighten concerns about effectively implementing the curriculum (Lin et al., 2023). These considerations suggest that the findings may require adaptation in other contexts, particularly those with differing educational priorities and resource availability. Thus, future research could address these issues by including teachers from diverse cultural and educational settings, as well as regions with varying economic conditions, providing a deeper understanding of how these contextual factors influence teachers' concerns about teaching AI.

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Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article. All authors have confirmed that no partial financial support was received. There is no potential conflict of interest between the authors in this study.

Ethical approval This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Institutional Review Board (IRB) of the South China Normal University approved this study, SCNU-JXJ-2021-009.

References

Akgun, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. *AI and Ethics, 2*, 431–440. https://doi.org/10.1007/s43681-021-00096-7

Aler Tubella, A., Mora-Cantallops, M., & Nieves, J. C. (2024). How to teach responsible AI in Higher Education: Challenges and opportunities. *Ethics and Information Technology, 26*(1), 3. https://doi.org/10.1007/s10676-023-09733-7

Al-Furaih, S. A. A., & Al-Awidi, H. M. (2020). Teachers' change readiness for the adoption of smartphone technology: Personal concerns and technological competency. *Technology, Knowledge and Learning, 25*(2), 409–432. https://doi.org/10.1007/s10758-018-9396-6

Ayanwale, M. A., Sanusi, I. T., Adelana, O. P., Aruleba, K. D., & Oyelere, S. S. (2022). Teachers' readiness and intention to teach artificial intelligence in schools. *Computers and Education: Artificial Intelligence, 3*, 100099. https://doi.org/10.1016/j.caeai.2022.100099

Baker-Doyle, K. J., Hunt, M., & Whitfield, L. C. (2018). Learning to fall forward: A study of teacher courage, equity, and freedom in the connected learning classroom. *The International Journal of Information and Learning Technology, 35*(5), 310–328. https://doi.org/10.1108/IJILT-05-2018-0053

Brandes, O., & Armoni, M. (2019). Using action research to distil research-based segments of pedagogical content knowledge of K-12 computer science teachers. In *Proceedings of the 2019 ACM conference on innovation and technology in computer science education* (pp. 485–491). https://doi.org/10.1145/3304221.3319773

Byrne, C., & Prendergast, M. (2020). Investigating the concerns of secondary school teachers towards curriculum reform. *Journal of Curriculum Studies, 52*(2), 286–306. https://doi.org/10.1080/00220272.2019.1643924

Casal-Otero, L., Catala, A., Fernández-Morante, C., Taboada, M., Cebreiro, B., & Barro, S. (2023). AI literacy in K-12: A systematic literature review. *International Journal of STEM Education, 10*(1), 29. https://doi.org/10.1186/s40594-023-00418-70

Chai, C. S., Ng, E. M. W., Li, W., Hong, H.-Y., & Koh, J. H. L. (2013). Validating and modelling technological pedagogical content knowledge framework among Asian preservice teachers. *Australasian Journal of Educational Technology, 29*(1), 41–53. https://doi.org/10.14742/ajet.174

Chai, C. S., Chiu, T. K., Wang, X., Jiang, F., & Lin, X. F. (2023). Modeling chinese secondary school students' behavioral intentions to learn artificial intelligence with the theory of planned behavior and self-determination theory. *Sustainability, 15*(1), 605. https://doi.org/10.3390/su15010605

Chai, C. S., Wang, X., & Xu, C. (2020). An extended theory of planned behavior for the modelling of Chinese secondary school students' intention to learn artificial intelligence. *Mathematics, 8*(11), 2089. https://doi.org/10.3390/math8112089

Chen, J. (2019). Exploring the impact of teacher emotions on their approaches to teaching: A structural equation modelling approach. *British Journal of Educational Psychology, 89*(1), 57–74. https://doi.org/10.1111/bjep.12220

Chen, L., Chen, P., & Lin, Z. (2020). Artificial intelligence in education: A review. *IEEE Access, 8*, 75264–75278. https://doi.org/10.1109/ACCESS.2020.2988510

Chen, X., Zou, D., Xie, H., Cheng, G., & Liu, C. (2022). Two decades of artificial intelligence in education: Contributors, collaborations, research topics, challenges, and future directions. *Educational Technology & Society, 25*(1), 28–47. https://doi.org/10.2307/48647028

Chen, Y.-H., & Jang, S.-J. (2014). Interrelationship between Stages of Concern and Technological, Pedagogical, and Content Knowledge: A study on Taiwanese senior high school in-service teachers. *Computers in Human Behavior, 32*(1), 79–91. https://doi.org/10.1016/j.chb.2013.11.011

Cheung, D., Hattie, J., & Ng, D. (2001). Reexamining the stages of concern questionnaire: A test of alternative models. *The Journal of Educational Research, 94*(4), 226–236.

Chiu, T. K. F., & Chai, C.-S. (2020). Sustainable curriculum planning for artificial intelligence education: A self-determination theory perspective. *Sustainability, 12*(14), 5568. https://doi.org/10.3390/su12145568

Chounta, I.-A., Bardone, E., Raudsep, A., & Pedaste, M. (2022). Exploring teachers' perceptions of artificial intelligence as a tool to support their practice in Estonian K-12 education. *International Journal of Artificial Intelligence in Education, 32*, 725–755. https://doi.org/10.1007/s40593-021-00243-5

Christesen, E., & Turner, J. (2014). Identifying teachers attending professional development by their stages of concern: Exploring attitudes and emotions. *The Teacher Educator, 49*(4), 232–246. https://doi.org/10.1080/08878730.2014.933641

Davis, J. P., & Bellocchi, A. (2018). Objectivity, subjectivity, and emotion in school science inquiry. *Journal of Research in Science Teaching, 55*(10), 1419–1447. https://doi.org/10.1002/tea.21461

Dele-Ajayi, O., Fasae, O. D., & Okoli, A. (2021). Teachers' concerns about integrating information and communication technologies in the classrooms. *PLoS ONE, 16*(5), e0249703. https://doi.org/10.1371/journal.pone.0249703

Fan, B., & Zhao, G. (2023, December). Unpacking chinese in-service teachers' concerns about integrating artificial intelligence into teaching from the perspective of a concerns-based adoption model. In *2023 twelfth international conference of educational innovation through technology (EITT)* (pp. 41–45). https://doi.org/10.1109/EITT61659.2023.00015.

Fullan, M. (2007). *The New Meaning of Educational Change*. Routledge.

Fuller, F. F. (1969). Concerns of teachers: A developmental conceptualization. *American Educational Research Journal, 6*(2), 207–226. https://doi.org/10.3102/00028312006002207

Geng, J., Jong, M.S.-Y., & Chai, C. S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher, 28*(1), 35–45. https://doi.org/10.1007/s40299-018-0414-1

Guo, L., Wang, D., Gu, F., Li, Y. Z., Wang, Y. Z., & Zhou, R. T. (2021). Evolution and trends in intelligent tutoring systems research: A multidisciplinary and scientometric view. *Asia Pacific Education Review, 22*(3), 441–461. https://doi.org/10.1007/s12564-021-09697-7

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2009). *Multivariate data analysis* (7th ed.). Prentice.

Hall, G. E., George, A. A., & Rutherford, W. L. (1977). *Measuring stages of concern about the innovation: A manual for use of the SoC Questionnaire (report No. 3032)*. The University of Texas at Austin. https://www.academia.edu/70617806/Measuring_Stages_of_Concern_about_the_Innovation_A_Manual_for_the_Use_of_the_SoC_Questionnaire

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process*. Suny Press.

Hao, Y., & Lee, K. S. (2015). Teachers' concern about integrating Web 2.0 technologies and its relationship with teacher characteristics. *Computers in Human Behavior, 48*, 1–8. https://doi.org/10.1016/j.chb.2015.01.028

Hao, Y., & Lee, K. S. (2016). Teaching in flipped classrooms: Exploring pre-service teachers' concerns. *Computers in Human Behavior, 57*, 250–260. https://doi.org/10.1016/j.chb.2015.12.022

Hao, Y., & Lee, K. S. (2017). Inquiry of pre-service teachers' concern about integrating Web 2.0 into instruction. *European Journal of Teacher Education, 40*(2), 191–209. https://doi.org/10.1080/02619768.2017.1285278

He, P., Zheng, C., & Li, T. (2021). Development and validation of an instrument for measuring chinese chemistry teachers' perceptions of pedagogical content knowledge for teaching chemistry core competencies. *Chemistry Education Research and Practice, 22*(2), 513–531. https://doi.org/10.1039/C9RP00286C

Hidayat, A. S. E., & Setyawan, F. (2020). Analysis of secondary school mathematics teachers' pedagogical content knowledge and intended teaching in curriculum reformation. *Journal of Physics: Conference Series, 1613*(1), 012082. https://doi.org/10.1088/1742-6596/1613/1/012082

Jiang, R. (2022). How does artificial intelligence empower EFL teaching and learning nowadays? A review on artificial intelligence in the EFL context. *Frontiers in Psychology, 13*, 1049401. https://doi.org/10.3389/fpsyg.2022.1049401

Jong, M. S. Y. (2022). Pilot study on concerns of teachers of using artificial intelligence in learning and teaching. In *2022 IEEE 5th Eurasian conference on educational innovation (ECEI)* (pp. 209–211). IEEE. https://doi.org/10.1109/ECEI53102.2022.9829459

Jong, M. S. Y. (2019). Sustaining the adoption of gamified outdoor social enquiry learning in high schools through addressing teachers' emerging concerns: A 3-year study. *British Journal of Educational Technology, 50*(3), 1275–1293. https://doi.org/10.1111/bjet.12767

Kennedy, E., & Shiel, G. (2024). The implementation of writing pedagogies in the Write to Read intervention in low-SES primary schools in Ireland. *Reading and Writing*. https://doi.org/10.1007/s11145-023-10510-7

Kim, D., So, H.-J., & Ryoo, D. (2021a). Unpacking teachers' concerns about CT-based pedagogy: The case of software education in Korea. *Computer Applications in Engineering Education, 29*(1), 66–82. https://doi.org/10.1002/cae.22343

Kim, S., Jang, Y., Choi, S., Kim, W., Jung, H., Kim, S., & Kim, H. (2021b). Analyzing teacher competency with TPACK for K-12 AI education. *AI-Artificial Intelligence, 35*(2), 139–151. https://doi.org/10.1007/s13218-021-00731-9

Lambriex-Schmitz, P., van der Klink, M. R., Beausaert, S., Bijker, M., & Segers, M. S. (2020). When innovation in education works: Stimulating teachers' innovative work behaviour. *International Journal of Training and Development, 24*, 118–134. https://doi.org/10.1111/ijtd.12175

Lau, W. W. F., & Jong, M. S. Y. (2022). Typology of teachers' stages of concern for STEM education. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2022.2064447

Lee, O., & Choi, E. (2015). The influence of professional development on teachers' implementation of the teaching personal and social responsibility model. *Journal of Teaching in Physical Education, 34*(4), 603–625. https://doi.org/10.1123/jtpe.2013-0223

Lin, X.-F., Chen, L., Chan, K. K., Peng, S., Chen, X., Xie, S., Liu, J., & Hu, Q. (2022). Teachers' perceptions of teaching sustainable artificial intelligence: A design frame perspective. *Sustainability, 14*(13), Article 13. https://doi.org/10.3390/su14137811

Lin, X.-F., Zhou, Y., Shen, W., Luo, G., Xian, X., & Pang, B. (2023). Modeling the structural relationships among Chinese secondary school student' computational thinking efficacy in learning AI, AI literacy, and approaches to learning AI. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-12029-4

Lindner, A., & Berges, M. (2020). Can you explain AI to me? Teachers' pre-concepts about Artificial Intelligence. In *2020 IEEE frontiers in education conference (FIE)* (pp. 1–9). IEEE. https://doi.org/10.1109/FIE44824.2020.9274136

Lindner, A., Romeike, R., Jasute, E., & Pozdniakov, S. (2019). Teachers' perspectives on artificial intelligence. In *12th international conference on informatics in schools, "Situation, evaluation and perspectives"* (pp. 22–29). Springer. https://www.researchgate.net/publication/337716601_Teachers'_Perspectives_on_Artificial_Intelligence

Little, T. D., Cunningham, W. A., Shahar, G., & Widaman, K. F. (2002). To parcel or not to parcel: Exploring the question, weighing the merits. *Structural Equation Modeling: A Multidisciplinary Journal, 9*(2), 151–173. https://doi.org/10.1207/S15328007SEM0902_1

Little, T., Rhemtulla, M., Gibson, K., & Schoemann, A. (2013). Why the items versus parcels controversy needn't be one. *Psychological Methods, 18*(3), 285–300. https://doi.org/10.1037/a0033266

Luft, J. A., Navy, S. L., Wong, S. S., & Hill, K. M. (2022). The first 5 years of teaching science: The beliefs, knowledge, practices, and opportunities to learn of secondary science teachers. *Journal of Research in Science Teaching, 59*(9), 1692–1725. https://doi.org/10.1002/tea.21771

Luik, P., Taimalu, M., Naruskov, K., & Kalk, K. (2024). Does knowledge according to the TPACK framework have an impact on student teachers'beliefs? A path analysis. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12767-z

Marsh, H. W., Hau, K.-T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) findings. *Structural Equation Modeling: A Multidisciplinary Journal, 11*(3), 320–341. https://doi.org/10.1207/s15328007sem1103_2

Martínez-Valdivia, E., de Pegalajar-Palomino, M. C., & Burgos-García, A. (2020). Social responsibility and university teacher training: Keys to commitment and social justice into schools. *Sustainability, 12*(15), 6179. https://doi.org/10.3390/su12156179

May, L. K., & Curtner-Smith, M. D. (2021). "My mindset has completely shifted from asking what to asking why and how": Influence of two effective and expert teachers' value orientations on their curricula and pedagogies. *European Physical Education Review, 27*(3), 543–558. https://doi.org/10.1177/1356336X20971335

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Moore, J. (2019). AI for not bad. *Frontiers in Big Data, 2*, 32. https://doi.org/10.3389/fdata.2019.00032

Mor Barak, M. E. (2020). The practice and science of social good: Emerging paths to positive social impact. *Research on Social Work Practice, 30*(2), 139–150. https://doi.org/10.1177/1049731517745600

Negru, I. A. (2023). Tools for assessing students' socio-emotional competencies. *A Systematic Literature Review. Journal of Educational Sciences, 20,* 113–127. https://doi.org/10.35923/JES.2023.1.07

Niño, M., Zicari, R. V., Ivanov, T., Hee, K., Mushtaq, N., Rosselli, M., Sánchez-Ocaña, C., Tolle, K., Blanco, J. M., Illarramendi, A., Besier, J., & Underwood, H. (2017). Data projects for "Social Good": Challenges and opportunities. *International Journal of Humanities and Social Sciences, 11*(5), 1094–1104. https://doi.org/10.5281/zenodo.1130095

Nuzzaci, A. (2016). Ethical use in the teaching of ICT and initial teacher training: A preliminary study on the descriptors of the observational tools. *International Journal of Digital Literacy and Digital Competence (IJDLDC), 7*(4), 17–36. https://doi.org/10.4018/IJDLDC.2016100102

Ohlemann, S., Imhof, M., & Bellhäuser, H. (2023). Implementing reform in the teacher education system: Concerns of teacher educators. *Teaching and Teacher Education, 126*, 104087. https://doi.org/10.1016/j.tate.2023.104087

Oleson, A., Mendez, C., Steine-Hanson, Z., Hilderbrand, C., Perdriau, C., Burnett, M., & Ko, A. J. (2018). Pedagogical content knowledge for teaching inclusive design. In *Proceedings of the 2018 ACM conference on international computing education research* (pp. 69–77). ACM. https://doi.org/10.1145/3230977.3230998

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(3), 261–284. https://doi.org/10.1007/s11165-007-9049-6

Pellikka, A., Nylen, T., Hirvensalo, V., Hynynen, L., Lutovac, S., & Muukkonen, P. (2024). Understanding teachers' perceptions of geomedia: Concerns about students' critical literacy. *Teaching and Teacher Education, 144*, 104607. https://doi.org/10.1016/j.tate.2024.104607

Pringle, R. M., Mesa, J., & Hayes, L. (2020). Meeting the demands of science reforms: A comprehensive professional development for practicing middle school teachers. *Research in Science Education, 50*(2), 709–737. https://doi.org/10.1007/s11165-018-9708-9

Rogers, W. M., & Schmitt, N. (2004). Parameter recovery and model fit using multidimensional composites: A comparison of four empirical parceling algorithms. *Multivariate Behavioral Research, 39*(3), 379–412. https://doi.org/10.1207/S15327906MBR3903_1

Sanusi, I. T., Oyelere, S. S., & Omidiora, J. O. (2022). Exploring teachers' preconceptions of teaching machine learning in high school: A preliminary insight from Africa. *Computers and Education Open, 3*, 100072. https://doi.org/10.1016/j.caeo.2021.100072

Serholt, S., Barendregt, W., Vasalou, A., Alves-Oliveira, P., Jones, A., Petisca, S., & Paiva, A. (2017). The case of classroom robots: Teachers' deliberations on the ethical tensions. *AI & Society, 32*, 613–631. https://doi.org/10.1007/s00146-016-0667-2

Shin, D. (2021). Teaching mathematics integrating intelligent tutoring systems: Investigating prospective teachers' concerns and TPACK. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-021-10221-x

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.2307/1175860

Song, P., & Wang, X. (2020). A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years. *Asia Pacific Education Review, 21*(3), 473–486. https://doi.org/10.1007/s12564-020-09640-2

Su, J., Zhong, Y., & Ng, D. T. K. (2022). A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence, 3*, 100065. https://doi.org/10.1016/j.caeai.2022.100065

Sulmont, E., Patitsas, E., & Cooperstock, J. R. (2019). Can you teach me to machine learn?. In *Proceedings of the 50th ACM technical symposium on computer science education* (pp. 948–954). ACM. https://doi.org/10.1145/3287324.3287392

Tedre, M., Toivonen, T., Kahila, J., Vartiainen, H., Valtonen, T., Jormanainen, I., & Pears, A. (2021). Teaching machine learning in K–12 classroom: Pedagogical and technological trajectories for artificial intelligence education. *IEEE Access, 9*, 110558–110572. https://doi.org/10.1109/ACCESS.2021.3097962

Teerling, A., Bernholt, A., Igler, J., Schlitter, T., Ohle-Peters, A., McElvany, N., & Köller, O. (2020). The attitude does matter: The role of principals' and teachers' concerns in an implementation process. *International Journal of Educational Research, 100*, 101528. https://doi.org/10.1016/j.ijer.2019.101528

Touretzky, D., Gardner-McCune, C., Breazeal, C., Martin, F., & Seehorn, D. (2019). A year in K-12 AI education. *AI Magazine, 40*(4), 88–90. https://doi.org/10.1609/aimag.v40i4.5289

Tsang, K. K., & Kwong, T. L. (2017). Teachers' emotions in the context of education reform: Labor process theory and social constructionism. *British Journal of Sociology of Education, 38*(6), 841–855. https://doi.org/10.1080/01425692.2016.1182007

Velander, J., Taiye, M. A., Otero, N., & Milrad, M. (2023). Artificial Intelligence in K-12 Education: Eliciting and reflecting on Swedish teachers' understanding of AI and its implications for teaching & learning. *Education and Information Technologies*. https://doi.org/10.1007/s10639-023-11990-4

Weddle, H. (2021). Team emotion matters: Exploring teacher collaboration dynamics over time. *Journal of Educational Change*. https://doi.org/10.1007/s10833-021-09436-0

Williams, R., Kaputsos, S. P., & Breazeal, C. (2021). Teacher perspectives on how to train your robot: A middle school AI and ethics curriculum. In *Proceedings of the AAAI conference on artificial intelligence* (pp. 15678–15686). EAAI. https://doi.org/10.1609/aaai.v35i17.17847

Yadav, A., & Berges, M. (2019). Computer science pedagogical content knowledge: Characterizing teacher performance. *ACM Transactions on Computing Education, 19*(3), 1–24. https://doi.org/10.1145/3303770

Yan, T., & Deng, M. (2018). Regular education teachers' concerns on inclusive education in China from the perspective of concerns-based adoption model. *International Journal of Inclusive Education, 23*(4), 384–404. https://doi.org/10.1080/13603116.2018.1435741

Yau, K. W., Chai, C. S., Chiu, T. K. F., Meng, H., King, I., & Yam, Y. (2023). A phenomenographic approach on teacher conceptions of teaching Artificial Intelligence (AI) in K-12 schools. *Education and Information Technologies, 28*(1), 1041–1064. https://doi.org/10.1007/s10639-022-11161-x

Yildiz Durak, H. (2021). Modeling of relations between K-12 teachers' TPACK levels and their technology integration self-efficacy, technology literacy levels, attitudes toward technology and usage objectives of social networks. *Interactive Learning Environments, 29*(7), 1136–1162. https://doi.org/10.1080/10494820.2019.1619591

Yue, M., Dai, Y., Siu-Yung, M., & Chai, C. S. (2021). An analysis of K-12 artificial intelligence curricula in eight countries. In *Proceedings of the 29th international conference on computers in education* (pp. 22–26). Asia Pacific Soc Computers in Education. https://icce2021.apsce.net/wp-content/uploads/2021/12/ICCE2021-Vol.II-PP.-769-773.pdf

Yue, M., Jong, M. S. Y., & Ng, D. T. K. (2024). Understanding K-12 teachers' technological pedagogical content knowledge readiness and attitudes toward artificial intelligence education. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-12621-2

Zembylas, M. (2006). *Teaching with emotion: A postmodern enactmen* (Illustrated). Information Age Publishing.

Zembylas, M. (2007). Emotional ecology: The intersection of emotional knowledge and pedagogical content knowledge in teaching. *Teaching and Teacher Education, 23*(4), 355–367. https://doi.org/10.1016/j.tate.2006.12.002

Zembylas, M. (2009). Teacher emotions in the context of educational reforms. *Second International Handbook of Educational Change*. https://doi.org/10.1007/978-90-481-2660-613

Zhang, H., Zhu, C., & Sang, G. (2014). Teachers' stages of concern for media literacy education and the integration of MLE in Chinese primary schools. *Asia Pacific Education Review, 15*(3), 459–471. https://doi.org/10.1007/s12564-014-9321-1