Constructing a teacher portrait for the artificial intelligence age based on the micro ecological system theory: A systematic review

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Abstract

Artificial intelligence (AI) is bringing new developments in education. Teachers' professional development grows with the promotion of technology, and more challenges and difficulties will be faced by teachers in the AI age. Thus, this study aimed to explore what a teacher portrait should be like in the new AI age. In order to systematically and comprehensively construct a teacher portrait for the AI age, we searched online databases using keywords, and after screening according to the inclusion and exclusion criteria, 26 journal documents were identified for in-depth analysis. It was found that there were 20 different types of frameworks that could be used to construct a teacher portrait for the AI age. This study reconstructed a teacher portrait based on the Person-Process-Content (PPC) structure of the micro ecological system theory, and finally arrived at a teacher portrait framework with three dimensions and eight sub-dimensions, including teachers' cognition and emotion, teachers' knowledge and skills, and interaction between teachers' cognition and ability, which highlighted the dynamic requirements of teachers' professional development in the AI age. In addition, the challenges faced by teachers in the AI age are mainly concentrated on four aspects: the upgrading of teacher training requirements, the change of educational environment, the teaching application of digital technology, and the ethical issues of artificial intelligence. These findings provide a direction for promoting the professional development of teachers in the AI age, and can help teachers better cope with the challenges of the new age.

Keywords Teacher portrait · AI age · Systematic review · Micro ecological system theory

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1 Introduction

There is a growing consensus in society that artificial intelligence (AI) has significant potential for use in education to enhance teaching effectiveness and efficiency (Chen et al., 2020; Devedzic, 2004). This agreement has arisen in recent years due to the emergence and maturation of AI applications in education, including intelligent tutor systems and intelligent evaluation. Indeed, AI is driving education reform and innovation at an unprecedented pace (Huang & Zheng, 2018). For instance, AI can innovate distance learning resources and teaching models (Zheng, 2017), and can be applied to teaching video analysis and innovate its application form (Li et al., 2021). AI can also cultivate students' key abilities through the establishment of AI courses (Huang, 2021), and can enrich and innovate the teaching content. AI has greatly promoted the innovation of learning and teaching, and has promoted the deep integration of technologies and education. The appearance of various emerging technologies has promoted systematic reforms in the field of education. The emergence of AI has transformed the teaching environment, teaching methods and evaluation methods. It has addressed numerous teaching challenges and optimized the teaching process. Simultaneously, teachers need to become proficient in using digital technology for teaching to adapt to the changes brought about by AI technology (Falloon, 2020; Gümüs & Kukul, 2022). They should receive training to update their knowledge (Instefjord & Munthe, 2016; Tang et al., 2022) and acquire ethical knowledge to guide their teaching practice (García & Lozano, 2021). This poses significant challenges to teachers' professional development.

Considering the change of teachers' functions in the technology-rich educational space, in recent decades, many teacher portrait frameworks have been established. For example, many frameworks of digital competency or digital literacy have been put forward to keep up with the rapid progress of information technologies (e.g., Basantes-Andrade et al., 2022; Tang et al., 2022). In addition, some frameworks are centered on teachers' knowledge, and summarize teachers' knowledge based on the TPACK framework (e.g., Ay et al., 2015; Yeh et al., 2021). The existing frameworks mainly provide a teacher portrait from the perspective of competence, literacy or knowledge (e.g., Basantes-Andrade et al., 2022; Cabero-Almenara et al., 2020; Margerum-Leys & Marx, 2004). In the existing frameworks, there is no lack of emphasis on comprehensiveness. However, in the face of the changes and challenges brought by AI, a new teacher portrait framework is needed. Therefore, it is important to systematically review the literature to sort out the frameworks of teachers' knowledge, literacy and competence. This will enable the outlining of a teacher portrait for the AI age, which will help teachers better cope with the challenges of this new era.

Bronfenbrenner (1979) proposed the micro ecological system theory to discuss the interaction among people, process and content. This theory provides a resource for describing a dynamic and overall portrait of teachers' professional quality (Socratous & Ioannou, 2022). There have been studies applying micro ecological theory to investigate the characteristics of teachers' professional

literacy and the quality of their professional development (Chu et al., 2021). The changes to education brought by AI have reconstructed a new type of ecology system in education. Teachers in the new educational system should firstly learn to equip themselves with new knowledge, literacy or competences to adapt to the changes. Thus, this study aimed to adopt the micro ecological system person-process-content model to construct a teacher portrait framework for the AI age. Based on a systematic review of previous studies' frameworks for teachers' knowledge, literacy, and competence, this study constructs a portrait of teachers facing the development of AI. The aim is to promote teachers' professional development to keep up with the times.

2 Literature Review

2.1 Artificial intelligence application in education

Artificial intelligence, as a term, was first put forward at Dartmouth Conference in 1956 to refer to letting computers simulate human intelligence (McCarthy et al., 2006). In the field of education, due to limitations of immature technology and incomplete Internet coverage, AI was not widely used until the 1990s (Salas-Pilco & Yang, 2022). In recent years, AI in education has entered an unparalleled phase of rapid development because of the ongoing maturity of cloud computing, educational big data, deep learning, and other technologies, as well as the support of national policy guidelines (Ye et al., 2021).

The application of AI provides new opportunities for traditional teaching and also provides new ways to optimize teaching. For instance, AI teaching assistants provide students with personal and immediate responses (Kim et al., 2020) and improve teachers' teaching practice (An et al., 2023). Intelligent tutoring systems provide students with the most suitable problem-solving models and prompting models (Anohina, 2007). Learning analytics represents data about learners so as to improve learning, which provides a new perspective for teachers to understand education (Clow, 2013). The intelligent evaluation process is designed to be objective, providing independent assessments of learners' learning processes and behaviours. This enables teachers to receive personalized learning evaluation results, which can help improve teaching methods and adjust teaching priorities (Qu et al., 2022).

At the same time, teachers are also facing challenges in the AI age. In terms of cultivating students, teachers should pay more attention to students' cognitive development and thinking improvement. Students are surrounded by direct access to mass information and rapidly developing technologies (Jimoyiannis, 2013), they are required to develop higher-order learning skills such as critical thinking, problem solving, creativity, meta-cognition, communication, digital and technological literacy, civic responsibility, and global awareness (Kim et al., 2019). As far as teachers are concerned, they should not only have the above competences, literacy or knowledge, but also learn how to cultivate these qualities in their students. Thus, the abilities or competences that teachers should pay attention to and improve are multi-dimensional. In addition, the development and use of various intelligent platforms

have also changed teachers' working environment, such as a big data teaching platform (Lin, 2016), a teaching quality big data monitoring platform (Qin et al., 2020), and an intelligent decision support education platform (Liu et al., 2021). Teachers need to pay attention to the teaching advantages of these intelligent platforms, effectively apply them to teaching practice, and constantly adjust their abilities to adapt to the teaching environment based on AI technology. Furthermore, the use of AI technology also causes ethical problems. Therefore, when utilizing technology, teachers should take into account the emotional worth of their students and their own opinions about it. And at the same time, they should utilize technology responsibly and avoid abusing it or relying on it excessively. Teachers must also have the knowledge to evaluate AI-based decisions (Celik, 2022). Given these challenges, it is crucial to continue promoting teachers' professional growth in the AI age.

2.2 Teacher portrait

The concept of a teacher portrait can be traced back to the user portrait concept developed by Alan Cooper, where a user portrait is the virtual representation of actual users and the target user model based on real data mining and user construction (Cooper, 2004). The description of a user portrait mainly depends on frameworks or models. For example, Jiang and Yin (2022) proposed an innovative semi-supervised social network user portrait analysis model (UPAM) based on the user portrait model to integrate relevant information about users into a unified topic model framework. On the basis of the Reference Forward Model (RFM), Liu and Deng (2022) introduced the subject of user portrait modeling under big data.

Unfortunately, few studies have clearly proposed the concept of a teacher portrait. Previous studies tended to interpret a teacher portrait as a description of frameworks based on data. For instance, based on the teacher efficacy framework, data reflecting the general efficacy, personal efficacy and collective efficacy of teachers were collected, and a teacher portrait at high and low implementation levels was developed (Cantrell & Callaway, 2008). In addition, Long and Hoy (2006) proposed that teachers' interest is a complex concept made up of cognitive, affective, motivational, and volitional elements, and then used a composite portrait to describe the teachers' interests. There are researchers who hope to describe the "ideal portrait" of an educator, showing the ensemble of the qualities and personality traits necessary for those who devote themselves to teaching and education (Maria-Cristina, 2015). Based on this, the description of teachers' traits in the current teacher portraits is not comprehensive, such as only paying attention to teachers' efficacy (Cantrell & Callaway, 2008) or teachers' interest (Long & Hoy, 2006). It is worth noting that a framework can systematically present the structure of a teacher portrait and is the basis for describing a teacher portrait. Therefore, it is meaningful to summarize a comprehensive and systematic framework to construct a teacher portrait.

In recent years, in the face of the challenges brought by AI technologies to teachers' development, a large number of frameworks have portrayed teachers' information literacy (Nieto-Isidro et al., 2021), data literacy (Quaicoe & Pata, 2020), digital competence (Krumsvik, 2014) or AI teaching ability (Sun et al., 2022). Such as the

ISEC teachers' competency model (Weng et al., 2020), the VATK standard (Wiens et al., 2022), the UNESCO ICT competency framework for teachers (Villar et al., 2022), the intelligent—TPACK framework (Celik, 2022), and so on. These frameworks reflect the knowledge, literacy or competence that teachers should have in the AI age, and provide important guidance for teachers' development. With a growing number of frameworks describing teachers' knowledge, literacy and competence, it is necessary to sort out the existing frameworks and form a comprehensive and integral framework. From these points of view, some scholars have undertaken this work and achieved some successful results. Margerum-Leys & Marx (2004) constructed a comprehensive description of teachers' knowledge on the basis of Shulman's model of teachers' knowledge. Uerz et al. (2018) concluded four domains of teachers' competence in preparing their students to teach with technology based on an overview of 26 relevant research articles. Cabero-Almenara et al. (2020) selected the most suitable "Teacher Digital Literacy" framework by comparing the seven most commonly used competence frameworks in international contexts. Basantes-Andrade et al. (2022) reviewed 26 papers about teachers' digital competence to summarize the basic standards in digital competence, so as to strengthen their work inside and outside the classroom. However, these reviews of teacher portraits are just from one perspective such as knowledge, literacy or competence. There is no comprehensive review of contemporary teacher portraits. As a result, it is necessary to systematically reconstruct these frameworks to describe a teacher portrait in the AI age.

2.3 Micro ecological system theory

Bronfenbrenner's (1979) ecological systems theory (EST) is regarded as a suitable theory to describe and explain the ideas and actions of individuals and groups within the particular environment in which they exist (Ye et al., 2023). The EST places a developing human within a nested ecological system consisting of microsystem, mesosystem, exosystem, macrosystem, and chronosystem (Bronfenbrenner, 2005). The microsystem is defined as the immediate environment in which a person interacts with others during activities and develops some kind of interpersonal relationships (Bronfenbrenner, 1989). Originally, the Person-Process-Context (PPC) model of this theory can be used to analyze the variability of development results, which is a function of individual and environmental characteristics (Bronfenbrenner, 1989). For example, based on this model, the influence of social culture on the development of sports skills was discussed (Nobre et al., 2020), and to explore the relationship between preschool children's compliance level and children's temperament, child care quality and other factors (Wachs et al., 2004). The "Person" in this model relates to three types of related characteristics: demand, resource, and force (Bronfenbrenner and Morris, 2006). "Process" is described as "proximal processes," which relate to individuals' attributes with the context around them in an interactive and practically-reflective manner (DiSanti & Erickson, 2020). With the development of this theory, researchers began to pay attention to the Person-Process-Content (PPC) model. Compared with the original model, the "C" has changed. In order to explore the relationship between addiction and learning, Hong et al. (2021)
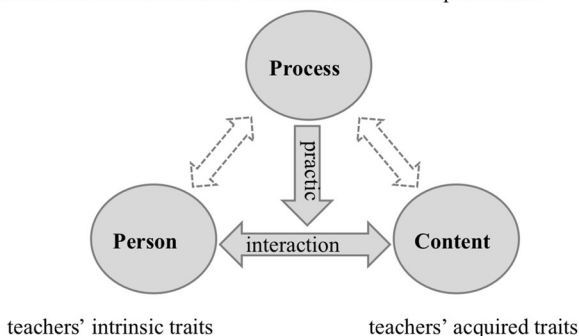
defined "Person" as students' short video addition state, "Process" as their pursuit and excitement for learning tasks, and "Content" as their behavioral performance in the classroom. Subsequently, inspired by this, Ye et al. (2023) built a research model on short video addiction based on this model.

In addition, the theory has been widely used to study the professional development of teachers. It highlights the significance of interacting environments and relationships that can affect teachers' social and emotional growth as well as educational outcomes. For example, for the PPC model, Gabbard and Krebs (2012) believed that "Person" refers to individual cognition and emotion; "Process" refers to the combination and connection between people and content; and "Content" refers to interactive objects and environments. Edwards and Burns (2016) summarized the ecological effects of taking measures to study the growth of English teachers from the perspective of a micro ecological system. According to Bronfenbrenner's (1979) micro ecological system theory, Chu et al. (2021) identified factors related to the professional quality of excellent English teachers. Based on micro ecological system theory, Nazari et al. (2022) explored the emotions of young learners of English teachers and their contribution to their identity construction, and found that teachers' emotions and identities are affected by the micro-classroom ecology of teaching.

Based on previous studies, the PPC model is an important tool to study the characteristics and the relationship between characteristics, which is conducive to a comprehensive understanding of the formation of teacher professional development. The development of teachers in the AI age takes place in interactions with the living and working ecology around them. The micro-ecosystem theory provides ideas for describing a teacher portrait in the AI age, emphasizing the interaction between teachers and an intelligent environment in the process of teachers adapting to the AI-supported environment. Therefore, this study analyzed the construction of a teacher portrait for the AI age from the perspective of the micro ecosystem theory. For the three elements in PPC, combined with the requirements of a "teacher portrait" for representation of teachers' traits, it is embodied as follows: "Person" refers to teachers' intrinsic traits, such as cognition and emotion; "Content" refers to teachers' acquired traits, such as knowledge and skills; and "Process" refers to the interaction between teachers' intrinsic traits

Fig. 1 The PPC theoretical framework

Interaction between teachers' intrinsic traits and acquired traits

Process

practic

Person   interaction   Content

teachers' intrinsic traits   teachers' acquired traits

and acquired traits, such as the interaction between teachers' cognition and ability, that is, teachers' practice (see Fig. 1).

2.4 Research questions

Therefore, based on the micro ecology system theory, this study aimed to adopt the systematic review method to explore the existing teachers' knowledge, literacy and competency frameworks to construct a teacher portrait framework for the AI age. In line with this purpose, the following questions were proposed:

  RQ1: What frameworks can be used to describe a teacher portrait for the AI age?
  RQ2: What should the teacher portrait be like in the AI age?
  RQ3: What challenges will teachers face in the AI age?

3 Method

3.1 Search process

This study aimed to provide a feasible teacher portrait for teachers' professional development, so as to optimize the development path of teachers in the AI age. This study holds that a teacher portrait in the AI age should comprise knowledge, literacy and competency. Nowadays, teachers are surrounded by various digital technologies (Pan, 2021). Digital competence is crucial to their professional development and is an important foundation to adapt to the teaching environment in the AI age. In order to retrieve as many documents as possible to reveal the traits that teachers should have in the AI age, this study selected the Web of Science, Science Direct and ERIC as the search databases, and conducted the search in December 2022. In order to extract more comprehensive and usable frameworks from the retrieved literature, and to ensure that these frameworks are structural descriptions of teachers' knowledge, literacy or competence, the search keywords were determined as "(framework or model) and (teacher or facility) and (competence or literacy or knowledge)." With the deepening of the research, after thinking and discussion, the research team decided to add "AI" as the retrieval keyword, so that the retrieved literature can focus more on the development of teachers in the AI age and provide more appropriate support for the construction of a teacher portrait in the AI age. Therefore, the literature finally retrieved in this study is based on the following keywords: "AI and (framework or model) and (teacher or facility) and (competence or literacy or knowledge)." Besides, teachers teaching in different stages were not distinguished, since the study focused on the general traits of teachers as a profession in the AI age. Therefore, the choice of frameworks should not be limited to a group of teachers at a certain stage, but should be more inclusive.

3.2 Inclusion and exclusion criteria

After removing 11 duplicate records, 284 unique records remained. The records were published in English from 1997 to 2022. As early as 1985, there were scholars who pointed out that a variety of disciplines can be taught or tutored using intelligent computer-assisted instruction (ICAI) systems, and that expert systems can help with educational diagnostics and assessments (Jones, 1985). Computer tutors based on certain pedagogical principles can be used to teach students to do geometric proofs, and so on (Anderson et al., 1985). It can be seen that the application advantages of AI in teaching were discovered and proposed very early. However, the concept of "digital literacy" for teachers was relatively lagging. Gilster (1997) first proposed "digital literacy," which gradually evolved into "digital competency" (Janssen et al., 2013). From the perspective of machine learning, fully mastering AI requires data literacy (Olari & Romeike, 2021), and individuals need to know how to use computers to understand artificial intelligence, so digital literacy is a prerequisite for AI literacy (Long & Magerko, 2020). Considering that data literacy or digital literacy is closely related to a teacher portrait in the AI age, this study determined the time of record inclusion as 1997 to the present, and the records related to "AI, digital skill, digitability, digital literacy, data literacy, digital competency" were included first. The aim is to identify the most valuable documents and frameworks. In order to achieve the final research goal, which was to construct a teacher portrait framework for the AI age, the final records should present the traits that teachers should have in terms of knowledge, literacy or competency in detail, and have clear research methods and structural descriptions of frameworks, models, standards or scales. Therefore, the final inclusion and exit criteria are shown in Table 1.
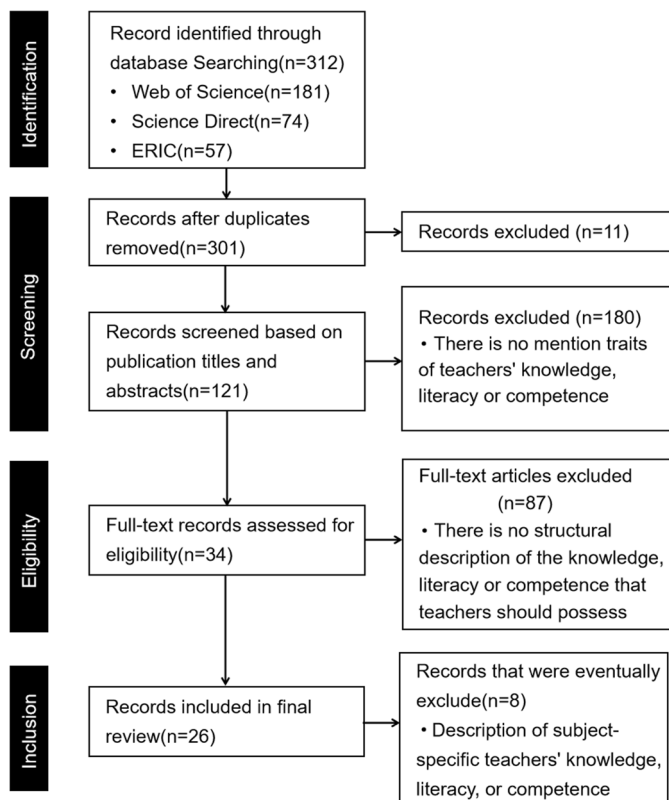
3.3 Selection process

The record selection process was divided into three phases. In the first phase, 180 records without teachers' knowledge, literacy or competency were excluded based on a review of the title and abstract. In the second phase, the remaining 121 records were reviewed in full by researchers in the team, from which 87 records that did not provide a structural description of the knowledge, literacy or competency that teachers should possess were excluded. In the third phase, the remaining 34 records were coded, and the records that did not meet the criteria in the coding process were excluded. A total of eight relevant articles on particular subjects were excluded. The final 26 records were analyzed in depth. The reasons for exclusions and an overview of the search process can be found in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement diagram in Fig. 2 (Moher et al., 2009).

Table 1 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Time frame	Records published between 1997 and 2022	Records published before 1997 and after 2022
Language	Records published in English	Records published in languages other than English
Sector	Records focusing on relevant competence, literacy or knowledge that teachers should possess	Records do not point out what competence, literacy or knowledge teachers should possess
Methodological design	Records have a clearly evidenced methodological design	Records do not have a clearly evidenced methodological design
Structural description	Records that describe the structural content of teachers in terms of competence, literacy or knowledge	Records that provide an unstructured description or study of particular subjects

Fig. 2 The process of inclusion and exclusion

3.4 Data Analysis

For the 26 records that ultimately qualified for in-depth analysis, in order to answer the research questions. Firstly, two coders used the same data extraction table to code independently, the coding information include: (1) title, (2) publication year, (3) journal impact factors, (4) citation times, (5) research methods, (6) knowledge framework, (7) literacy framework, (8) competency framework, (9) challenges in the AI age. Secondly, we classified and counted the journal impact factors, citation times and research methods to ensure that the included records were of in-depth analysis value. Finally, according to the extracted frameworks related to teachers and the information about the challenges faced by teachers in the AI age, the PPC model was used as the coding basis for qualitative analysis. The encoding analysis process of frameworks was based on Fig. 1 (1. teachers' intrinsic traits; 2. teachers' acquired traits; 3. interaction between teachers' intrinsic traits and acquired traits). In the encoding process, if the dimensions in different frameworks had the same or overlapping meanings, they were merged and re-encoded. After all the dimensions were divided into three categories, the dimensions in the three categories were classified respectively, and finally a teacher portrait with three dimensions and eight sub-dimensions was obtained.
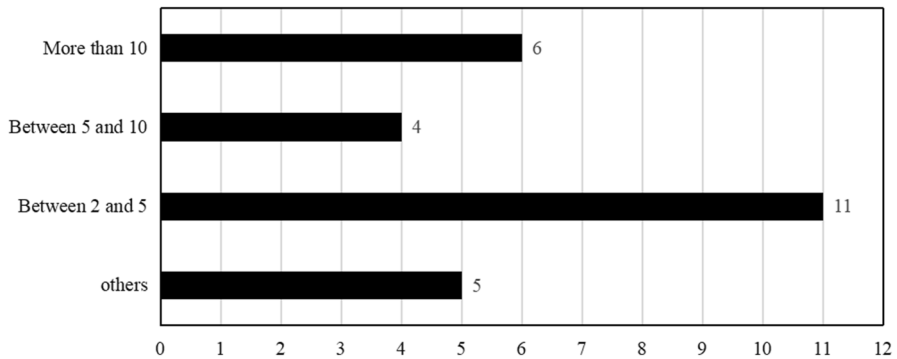
Fig. 3 Journal impact factor distribution

The coding analysis of the extracted information about the challenges faced by teachers in the AI age was also based on the PPC model. So the challenge faced by teachers was defined as "application of digital technology in teaching" (person), "teacher training requirements have been upgraded" (process) and "the educational environment has changed" (content). Challenges that did not belong to these three categories were placed in the "other" category. After analyzing the "other" category, an additional challenge, namely "ethical issues of artificial intelligence," was generated, and these four types of challenges were counted.

The extraction and coding of data were completed by two researchers under the guidance of an expert in the field of educational artificial intelligence. In the initial stage, the two researchers reached a consensus on the coding standard. Each researcher coded all the included records, and stipulated that the information related to the frameworks and challenges should be based on the context of the article, thus making the coding result more accurate. After all the coding was finished, two researchers cross-checked (McFadden & Williams, 2020) to ensure the correctness of the results. For different coding results, the two researchers consulted books and documents and resolved them through discussion with the expert until they reached 100% agreement (Bereczki & Kárpáti, 2018).

4 Results

4.1 The frameworks used to construct a teacher portrait for the AI age

A quantitative analysis method was used to extract the basic information of the 26 records that were finally included. The count of research methods was based on the classification of research methods in a study (Chu & Ke, 2017). The results showed that the impact factor and citation times of the journals that included the records were at a relatively high level. Among the included records, six were located in journals with an impact factor of more than 10 (see Fig. 3), and the citation times of the six records reached more than 50 (see Fig. 4). All of these data indicated that the final included records had high analytical value.
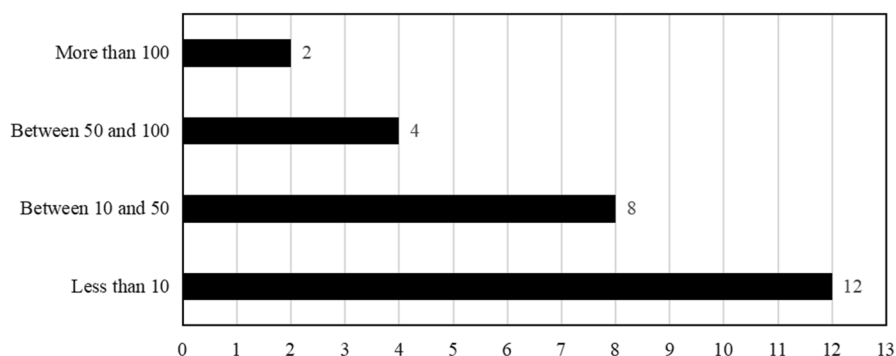
Fig. 4 Citation frequency distribution of the literature

In terms of the use of research methods, most studies tended to form structural descriptions of teachers' knowledge, literacy or competency through Delphi studies, usually called frameworks, models, standards or scales, and tested their effectiveness in the form of questionnaires. Therefore, some records used a variety of research methods. As shown in Fig. 5, eight records adopted a Delphi study and five adopted the questionnaire survey method. The most frequently used research method was the Delphi study, followed by the questionnaire survey method.

The frameworks of teachers' knowledge, literacy or competency mentioned in 26 records were extracted and are presented in Table 2. The preliminary classification of the frameworks mentioned in the 26 records showed that there were 20 different types of frameworks (see Table 2), among which 11 records were related to teacher competency, three were related to TPACK, and six were other related frameworks. These frameworks provide support for teachers' professional development and were an important basis for the formation of a teacher portrait for the AI age.

Firstly, the frameworks related to teacher competence include "ISEC teachers' competency model" "DigCompEdu" "Teachers' digital competence evaluation
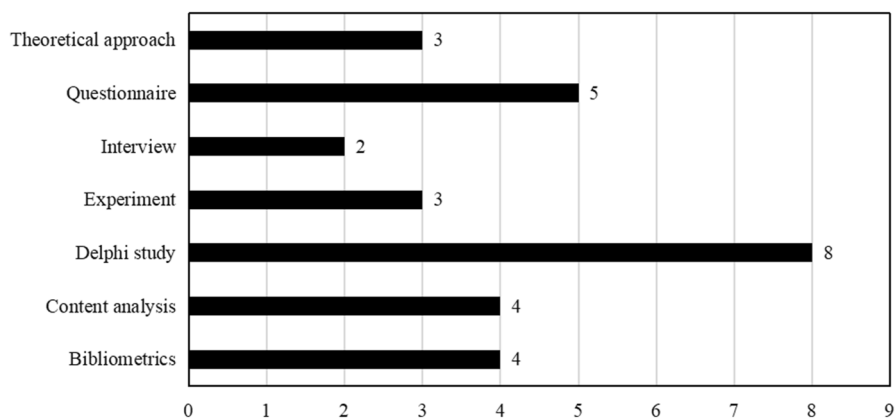

Fig. 5 The distribution of the application of research methods

Table 2 Summary of frameworks in different studies

Frameworks	Dimensions	Source
ISEC teachers' competency model	Critical Thinking; Instructional Design; Learning Assessment; Teaching in classroom; English as Medium of Instruction; Textbook Compilation; Curriculum Development; Pedagogical Innovation; International Cooperation; Competency for Education for Sustainable Development (ESD)	Weng et al., 2020
DigCompEdu	Professional Engagement; Digital Resources; Teaching and Learning; Assessment; Empowering Learners; Facilitating Learners' Digital Competence	Caena & Redecker, 2019; Lucas et al., 2021; Cabero-Almenara et al., 2020
TPACK framework	Technological Knowledge (TK); Pedagogical Knowledge (PK); Content Knowledge (CK); Technological Content Knowledge (TCK); Pedagogical Content Knowledge (PCK); Technological Pedagogical Knowledge (TPK); Technological Pedagogical Content Knowledge (TPACK)	Chai et al., 2011; Koh & Chai, 2016; Yeh et al., 2021; Olofson et al., 2016
Teachers' digital competence evaluation framework	Technical Knowledge; Learner Knowledge; Pedagogical Knowledge; Ethical Knowledge; Learner Technical Knowledge; Learner Pedagogical Knowledge; Learner Ethical Knowledge; Technical Pedagogical Knowledge; Technical Ethical Knowledge; Pedagogical Ethical Knowledge	Tang et al., 2022
VATK standard	Learner Development; Learning Differences; Learning Environments; Assessment; Instructional Strategies	Wiens et al., 2022
Digital competency scale	Safety; Data Literacy; Problem Solving; Digital Content Creation; Communication and Collaboration; Ethics	Gümüş & Kukul, 2022
Seven digital learning domains	Information Collection; Information Evaluation; Information Management; Information Processing; Teamwork; Integrity Awareness; Social Responsibility	Peled et al., 2021

Table 2 (continued)

Frameworks	Dimensions	Source
Conceptual framework teacher digital competence	Curriculum Competencies; Personal-ethical Competencies; Personal-professional Competencies; The Integration of Personal-ethical and Personal-professional Competencies	Falloon, 2020
Teacher knowledge	Content Knowledge; Pedagogical Knowledge; Pedagogical Content Knowledge	Margerum-Leys & Marx, 2004
Conceptual framework for DLFT	Content Knowledge; General Pedagogical Knowledge; Curriculum Knowledge; Pedagogical Content Knowledge; Knowledge of Learners and Their Characteristics; Knowledge of Educational Contexts; Knowledge of Educational Ends	Mandinach & Gummer, 2016
DT framework	Generator and Manager of Emerging Educational Practices; Expert in Digital Educational Content; A Reflective-practitioner Expanded; Expert in Enhanced Organizational or Personal Learning Contexts; Sensitive to the Use of Technology from the Social Commitment Perspective; Able to Use Technology to Expand his/her Relationship with the Student's Family and Environment	Castañeda et al., 2021
Descriptions of teachers' digital competence	Technology Proficiency; Pedagogical Compatibility; Social Awareness	Instefjord & Munthe, 2016
Training needs	Teaching; Research and Professional Development; Management; Communication and Collaboration; Develop Student Digital Competence	Basantes-Andrade et al., 2022
Digital competence in teacher training	Ethics and Morality	García & Lozano, 2021
UNESCO ICT competency framework for teachers	Application of Digital Skills; Teacher Professional Learning; Teacher Professional Development; Pedagogy, Policy and Vision; Understanding ICT in Education; Curriculum and Assessment	Villar et al., 2022

Table 2 (continued)

Frameworks	Dimensions	Source
MKT framework	Common Content Knowledge (CCK); Specialized Content Knowledge (SCK); Horizon Content Knowledge (HCK); Knowledge of Content and Students (KCS); Knowledge of Content and Teaching (KCT); Knowledge of Content and Curriculum (KCC)	Koponen et al., 2019
The common framework for teaching digital competence	Information and Information Literacy; Communication and Collaboration; Creation of Digital Content; Security; Problem Resolution	Sanchez-Cruzado et al., 2021; Garzón-Artacho et al., 2021
TPACK—practical model	Using ICT to Understand Students; Using ICT to Understand Subject Content; Planning ICT—Infused Curricula; Using ICT Representations; Using ICT—Integrated Teaching Strategies; Applying ICT to Instructional Management; Infusing ICT into Teaching Contexts; Using ICT to Assess Students	Ay et al., 2015
Intelligent—TPACK framework	Intelligence—TK; Intelligence—TPK; Intelligence—TCK; Intelligence—TPACK; Ethics	Celik, 2022
AI teaching competency	AI Teaching Knowledge; AI Teaching Skills; AI Teaching Self-efficacy	Sun et al., 2022

framework" "Digital competency scale" "Conceptual framework of teacher digital competence" "DT framework" "Descriptions of teachers' digital competence" "Digital competence in teacher training" "UNESCO ICT competency framework for teachers" "The common framework for teaching digital competence" "AI teaching competency". Among them, ISEC teacher competency model was established in the international academic exchange curriculum program, with special emphasis on the cultivation of teaching ability, and this model integrates ESD competency into the original teacher model. As a result, the evaluation dimensions of the existing model were expanded from nine to 10. It emphasizes the cultivation of teachers' ESD ability so as to provide systematic training for teachers (Weng et al., 2020). The European Framework for Digital Competence for Educators (DigCompEdu) is a teacher development framework based on the integration of existing tools and the results of consultation with teachers, researchers and decision makers. The framework is broader and views educators' digital competencies as a combination of knowledge, skills and attitudes, providing a common framework of reference for national, regional and local initiatives (Caena & Redecker, 2019). The UNESCO ICT competency framework for teachers is divided into six areas of teaching practice and three levels of teacher use of ICTs in teaching, laying the foundation for the digital evolution of teacher training (Villar et al., 2022). AI teaching competency is designed based on the TPACK framework to promote the professional development of computer science teachers (Sun et al., 2022).

Secondly, the frameworks related to TPACK include "TPACK framework" "TPACK—practical model" "Intelligent-TPACK framework". The TPACK framework covers seven different types of teacher expertise that teachers need to effectively integrate technology into their teaching (Chai et al., 2011). Existing TPACK research has clarified strategies to support teachers in creating TPACK, and it provides a starting point for understanding the design frameworks that may be relevant (Koh & Chai, 2016). For example, the TPACK-practice model developed on the basis of TPACK makes the practice of the TPACK framework more specific (Ay et al., 2015). The intelligent-TPACK framework integrates the technical knowledge and teaching knowledge based on artificial intelligence teaching tools, and extends the TPACK framework on ethics (Celik, 2022).

Thirdly, the remaining frameworks are "VATK standard" "Seven digital learning domains" "Teacher knowledge" "conceptual framework for DLFT" "training needs" "MKT framework". Among them, the VATK (Video Assessment of Teacher Knowledge) standard is a video-based knowledge assessment method of teacher knowledge of effective teaching, which can provide information about teacher candidate teaching knowledge at important moments in the training plans and teaching field (Wiens et al., 2022). The DLFT (Data Literacy for Teachers) conceptual framework outlines the particular skills, dispositions, and knowledge that teachers need to possess in order to use data in an ethical and successful manner (Mandinach & Gummer, 2016). The MKT (Mathematical Knowledge for Teaching) framework presents a systematic classification method of teachers' knowledge, which can be used to investigate and evaluate teachers' knowledge (Koponen et al., 2019).

Based on the analysis above, the extracted frameworks contain traits related to teachers' knowledge, literacy or competence. Two frameworks, Intelligent-TPACK

framework and AI teaching competency, were specifically proposed for AI, while the others were weak in specifically targeting the development of teachers in the AI age. This was a problem that needed to be overcome in this study. From the perspective of the development and change of the times, this is reasonable, because the name of the age has been constantly changing from the information age, the digital age, to the AI age. Therefore, the AI age is not in fact a separate age, but rather a progression from quantitative change to qualitative change with the continuous development of AI technology. In this process, AI technology is being gradually integrated into teaching and learning. As a result, the teaching environment has undergone significant changes, which is different from the requirements for teachers in the information age. In the AI age, teachers must shift their focus to their roles, responsibilities, and abilities under the influence of AI technology. This will enable them to master AI tools and teaching methods, leading to a qualitative breakthrough in teacher development from the information age to the AI age. Currently, the 20 extracted frameworks demonstrate the influence of technological advancements on teacher development. These frameworks possess characteristics of digitalisation and intelligence, can serve the development of teachers in the AI age and provide an important basis for constructing a teacher portrait for the AI age.

4.2 A teacher portrait for the AI age

Micro ecological system theory is considered to be the most suitable theory for the construction of a teacher portrait for the AI age. Based on this, the formation of a teacher portrait is mainly divided into two stages. In the first stage, we analyzed the portraits of teachers mentioned in the existing teacher frameworks in Table 2 in detail. Combining with the three elements derived from PPC: teachers' intrinsic traits, teachers' acquired traits, and interaction between teachers' intrinsic traits and acquired traits, it puts forward three dimensions: teachers' cognition and emotion, teachers' knowledge and skills, and the interaction between teachers' cognition and ability. In the second stage, according to the different meanings of the three dimensions, combined with the dimensions of each framework in Table 2, teachers' cognition and emotion dimension can be summarized into two sub-dimensions, teachers' knowledge and skills can be summarized into three sub-dimensions, and teachers' interaction between cognition and ability can be summarized into three sub-dimensions. Therefore, as shown in Fig. 6, the teacher portrait in this study consists of three dimensions and eight sub-dimensions. The detailed description of dimensions is shown in Table 3.

4.2.1 Teachers' cognition and emotion

Teachers' cognition and emotion are two important factors affecting the quality of teaching and learning, which form the basis of teaching as an emotional and thought-provoking vocation in all aspects (Shi, 2021). With the development of AI technology, AI is expected to become AI thinking that infers and forms cognitive
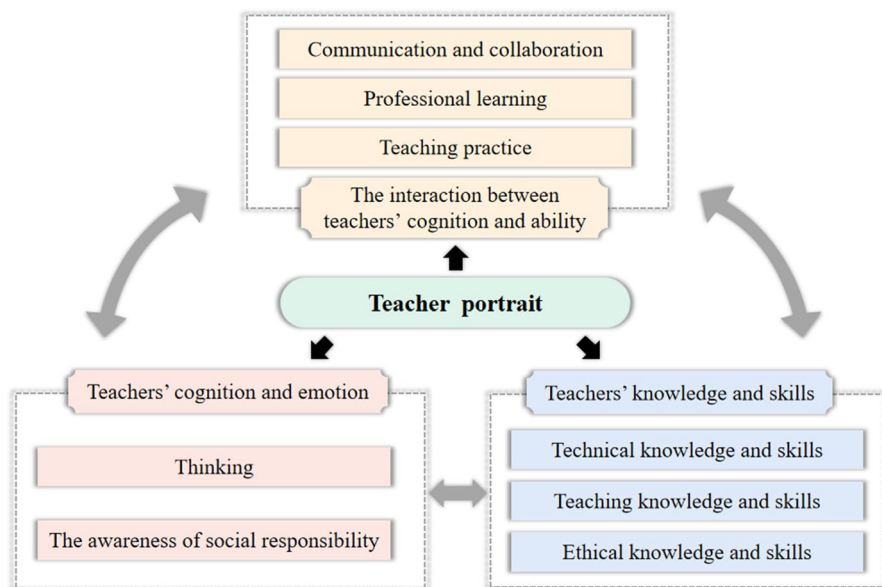
Fig. 6 Teacher portrait in the AI age

decisions like human beings (Etzioni & Etzioni, 2017). However, the interpersonal relationships and environments in real life are diverse, unpredictable and complex (Tan, 2020), and teachers' cognitive and emotional abilities cannot be replaced by AI. The development of human cognition is characterized by dialectical logic (Golombek & Doran, 2014). Teachers' cognition describes the complexity of mental lives (Borg, 2006), which is a systematic thinking development process. According to sociocultural theory, emotion originates from social interaction (Yang, 2019), which plays a catalytic role in teacher professional development. Based on this, we classified "Thinking" and "The awareness of social responsibility" as the dimensions of "Teachers' cognition and emotion". These are the fundamental manifestations of teachers' internal traits and the basic traits required of teachers in the AI environment.

The first sub-dimension in the teachers' cognition and emotion is thinking, including critical thinking, problem solving and teaching self-efficacy. Critical thinking is the basis of teachers' teaching practice and development. It helps teachers learn to analyze, verify and judge the real value of things with objective standards (Weng et al., 2020). The cultivation of critical thinking can promote the improvement of teachers' thinking skills, help teachers to correctly select and process teaching information, and thus ensure the effect of education and teaching. In addition, AI technology has changed the way teachers think, and a great deal of teachers' work has been replaced by AI. Critical thinking strategies can help teachers seek professional growth opportunities (Liao et al., 2022) and promote their own professional development. Problem-solving ability is also crucial. AI has brought many changes to education, liberating teachers from simple and repetitive work, and enabling teachers to

Table 3 Overview of dimensions and sub-dimensions of teacher portrait

Dimension	Sub-dimension	Description
Teachers' cognition and emotion (Person)	Thinking	• Critical thinking (Weng et al., 2020) • Problem Solving (Gümüs & Kukul, 2022; Sanchez-Cruzado et al., 2021; Garzón-Artacho et al., 2021)
	The awareness of social responsibility	• Safety / Security (Gümüs & Kukul, 2022; Sanchez-Cruzado et al., 2021; Garzón-Artacho et al., 2021) • Ethics and morality (García & Lozano, 2021) • Integrity awareness (Peled et al., 2021) • Social responsibility (Peled et al., 2021) • Social awareness (Instefjord & Munthe, 2016)
Teachers' knowledge and skills (Content)	Technical knowledge and skills	• Technological knowledge (Chai et al., 2011; Koh & Chai, 2016; Olofson et al., 2016; Yeh et al., 2021) • Technological pedagogical knowledge (Chai et al., 2011; Koh & Chai, 2016; Olofson et al., 2016; Yeh et al., 2021) • Competency for "Education for Sustainable Development" (ESD) (Weng et al., 2020) • Application of digital skills (Villar et al., 2022) • Technology proficiency (Instefjord & Munthe, 2016)
	Teaching knowledge and skills	• Pedagogical knowledge (Margerum-Leys & Marx, 2004; Yeh et al., 2021) • Curriculum knowledge (Mandinach & Gummer, 2016) • Learner knowledge (Tang et al., 2022; Wiens et al., 2022) • Content knowledge (Koponen et al., 2019; Margerum-Leys & Marx, 2004)
	Ethical knowledge and skills	• Learner ethical knowledge (Tang et al., 2022) • Technological ethical knowledge (Tang et al., 2022) • Pedagogical ethical knowledge (Tang et al., 2022) • The integration of personal-ethical and personal-professional competencies (Falloon, 2020)

Table 3 (continued)

Dimension	Sub-dimension	Description
The interaction between teacher cognition and ability (Process)	Teaching practice	• Instructional design (Weng et al., 2020) • Teaching in classroom (Weng et al., 2020) • Curriculum development (Weng et al., 2020) • Assessment (Caena and Redecker, 2019; Lucas et al., 2021; Cabero-Almenara et al., 2020; Wiens et al., 2022) • Reflect (Castañeda et al., 2021) • Management (Ay et al., 2015; Basantes-Andrade et al., 2022)
	Professional learning	• Research (Basantes-Andrade et al., 2022) • Teacher professional learning (Villar et al., 2022) • Teacher professional development (Basantes-Andrade et al., 2022; Villar et al., 2022)
	Communication and Collaboration	• Empowering learners (Lucas et al., 2021) • Teamwork (Peled et al., 2021) • International cooperation (Weng et al., 2020)

concentrate on complex and high-level work (Hwang et al., 2020). Therefore, teachers who are competent in the AI age need to improve their problem-solving ability. In addition, teaching self-efficacy is related to the degree of teachers' belief in successfully completing teaching, and the degree of effective perception may affect whether teachers take action and invest energy in their teaching (Tschannen-Moran & Hoy, 2001). Teachers need to have AI teaching self-efficacy (Sun et al., 2022), so that they can be competent for teaching successfully.

The second sub-dimension in the teachers' cognition and emotion is the awareness of social responsibility including safety, ethics and morality, integrity awareness, social responsibility and social awareness. Social responsibility refers to the awareness of threats and the understanding of social consequences related to personal behavior (Kurtz & Peled, 2016). Social awareness focuses on the influence of teachers' understanding and negotiation ability in cultural and social aspects (Instefjord & Munthe, 2016). Teachers with social awareness will be more able to foresee potential problems related to technology use and be more likely to achieve successful technology integration (Zhao et al., 2002). Therefore, the awareness of social responsibility requires teachers to realize their social mission and consciously pay attention to and respond to social development. Teachers are ethical-spiritual guides and role models for students (Tan, 2020). As professionals who have the ability to influence students' abilities, whether as individuals or as citizens who cultivate the ability to respect the environment, they must be responsible for their actions (Fernández et al., 2016). The use of teaching methods should take into account the healthy physical and mental development of students (Tang et al., 2022), and help students access and use digital resources in sustainable, safe and ethical ways (Falloon, 2020). In addition, teachers should take their responsibilities seriously and be accountable to the community, parents, and pupils, and pay attention to the changes and development of students' physical and mental health. In the face of risks and threats in the digital environment, teachers should take proactive preventive measures (Gümüs & Kukul, 2022) and use technology responsibly and safely in instruction and education (Sanchez-Cruzado et al., 2021). Therefore, ethics and moral knowledge require teachers to pay attention to ethical norms and the technical prevention of risk factors when using technology to educate their students.

4.2.2 Teachers' knowledge and skills

The content and nature of teachers' knowledge and skills are constantly evolving. With the deep integration of AI technology and education, the conceptualization of teachers' knowledge should fully represent the knowledge and abilities that teachers need to effectively navigate the technology-rich educational environment (Guerrero, 2005). Increasing teachers' theoretical and practical knowledge about AI in the educational environment can enhance teachers' trust in using AI technology (Nazaretsky et al., 2022). Deng and Zhang (2023) put forward Technical Pedagogical Content Ethical Knowledge (TPCEK) to deal with the ethical problems arising from digital technologies in teaching, and emphasized the importance of ethical knowledge. Based on this, we divided teachers' knowledge and skills into teaching knowledge and skills, technical knowledge and skills, and ethical knowledge and skills.

Because these are all environment-related acquired traits, teachers should constantly update their knowledge and skills system to meet the requirements of the times.

The first sub-dimension in teachers' knowledge and skills is teaching knowledge and skills, including pedagogical knowledge, curriculum knowledge, learner knowledge, and content knowledge. In the process of technical practice, pedagogical knowledge plays a vital role, and technology is used together with teaching strategies under the guidance of pedagogical knowledge (Yeh et al., 2021). Mastering the pedagogical knowledge is the basic link for teachers to successfully control technology. In addition, when using technology to guide teaching, teachers should be clear about the ongoing curriculum and the relationship between this curriculum and other curriculums (Mandinach & Gummer, 2016), so as to promote the continuity of the curriculum. Learner knowledge can be defined as the ability of teachers to adjust teaching methods and offer learners suitable learning taste according to their different characteristics, needs, and development levels (Tang et al., 2022; Wiens et al., 2022). Teaching supported by AI technology can realize personalized analysis of learners, and teachers should make decisions on this basis to better promote students' learning. Teachers' content knowledge should be constantly updated and changed with the surrounding environment (Margerum-Leys & Marx, 2004), so as to cultivate talents who can adapt to the AI environment. Based on the description of teachers' teaching knowledge and skills in the above four aspects, teachers are required to become lifelong learners and update their own knowledge and skills system at all times.

The second sub-dimension is technical knowledge and skills, including technological knowledge, technological pedagogical knowledge, competency for ESD, application of digital skills, and technology proficiency. Technological knowledge involves teachers' knowledge of operating computers and related software (Chai et al., 2011). With the help of technological knowledge, teachers can create and formulate solutions to teaching problems (Koh & Chai, 2016). In the absence of technological knowledge, teachers often choose to stay away from technical aspects instead of absorbing technological knowledge to deal with problems (Olofson et al., 2016). The application of AI technology in teaching requires teachers to actively learn technological knowledge to better adjust their own positioning. The integration of technological knowledge and pedagogical knowledge is conducive to improving teachers' ability to update pedagogical knowledge and innovate teaching models, so as to enhance the competency for ESD (Weng et al., 2020). According to the UNESCO ICT competence framework for teachers, the application of digital skills includes three stages: application, infusion and transformation, which requires teachers to gradually improve their technical application skills. Technology proficiency is considered as a teachers' technical ability and confidence in using technologies, which not only involves technological knowledge at the operational level, but also requires teachers to understand the relevant conditions for technology realization (Instefjord & Munthe, 2016). The existing frameworks all emphasize the importance of teachers' technical knowledge and skills to adapt to the educational development environment, which is an important part for teachers to meet the technical challenges of AI.

The third sub-dimension is ethical knowledge and skills, including learner ethical knowledge, technological ethical knowledge, pedagogical ethical knowledge,

and the integration of personal-ethical and personal-professional competencies. In terms of ethical knowledge and skills, teachers should know what is right, try to avoid wrong ideas or behaviors, and follow ethical practice in the use of digital technology, teaching design and guidance to students (Tang et al., 2022). Among them, learner ethical knowledge requires teachers to correctly handle the relationship with students, treat students correctly and teach them how to treat others correctly with ethical principles and values. Technological ethics knowledge includes teachers' protecting students' privacy and considering their emotional value when using technology to understand students, and teachers' rational use of technology to avoid excessive dependence or overuse (Tang et al., 2022). Teaching tools based on AI have teaching advantages, but also cause technical ethics problems. Teachers should have basic knowledge of artificial intelligence ethics (Celik, 2022). Teachers should understand how the AI system considers the fairness among learners and evaluate the accessibility of AI tools to ensure the fairness of teaching supported by AI technology (Celik, 2022). Therefore, technological ethical knowledge should been paid more attention on the rational use of AI technology in the teaching process and improve teachers' AI literacy (Ng et al., 2022), so that teachers can reasonably use technology to understand students without infringing on their privacy, and consider the influence of technology use on students' emotions and their acceptance of technology. Pedagogical ethical knowledge requires teachers to consider their pupils' physical and mental health growth and ensure the rationality of teaching content when choosing teaching methods. The integration of personal-ethical and personal-professional competencies requires teachers to assist students in acquiring and applying digital resources in a sustainable, ethical and safe way in their own professional fields (Falloon, 2020), and to abide by basic ethical norms.

4.2.3 The interaction between teachers' cognition and ability

Teachers' cognition refers to what teachers know, while teachers' ability refers to what teachers can do. The interaction between them reflects what teachers have done, that is, their practice. The construction of a teacher portrait should not only pay attention to the theoretical traits, but also integrate more practical traits and highlight the interaction between them. Furthermore, teachers should have the necessary skills to translate theoretical ideas into practice (Jeram & Davids, 2020). Based on this, this study classifies this dimension of teachers' traits as teaching practice, professional learning, communication and collaboration. Therefore, the traits of teachers' theory and practice form a closed loop, and the teacher portrait is comprehensively and dynamically described to meet the requirements of teachers' role reset in the AI age.

The first sub-dimension is teaching practice, including instructional design, teaching in the classroom, curriculum development, assessment, reflection, and management. Instructional design is challenging for teachers. All kinds of intelligent teaching platforms are put into use in teaching, which provide teachers with an open and shared environment for preparing lessons, and they can interact with students in time, so as to grasp the learning situation and adjust and improve the instructional design in time (Xue & Wang, 2022). Teachers should learn to use the

advantages of these intelligent platforms to effectively organize teaching content, teaching strategies and teaching resources. Teaching in the classroom requires teachers to use AI technology as a supplementary assistant to optimize the classroom teaching process (Xu & Ouyang, 2021) so as to effectively implement instructional design and achieve the teaching objectives. The massive data storage, calculation, retrieval and other functions of intelligent machines can help teachers to process and analyze data quickly, and replace teachers in the completion of many complex tasks (Li et al., 2022). Teachers' ways of transferring curriculum knowledge, evaluating teachers, reflecting and managing should be adjusted to adapt to the laws of education in the AI age. Curriculum development requires teachers to choose appropriate teaching content and activities, and creatively organize the design to achieve the corresponding teaching objectives (Weng et al., 2020). Assessment is mainly reflected in the use of digital technology to comprehensively analyze data to evaluate students (Caena & Redecker, 2019; Wiens et al., 2022), or self-assessment with tools (Lucas et al., 2021) and assessment of teaching content (Peled et al., 2021). The evaluation process supported by artificial intelligence technology adopts the same standard, and the evaluation result is more objective (Ahmad et al., 2022). Reflection is a very important element of teachers' professional development, which requires teachers to reflect on their actions and constantly improve their teaching practice through reflection (Castañeda et al., 2021). Management is an important ability requirement for teachers to ensure the orderly development of teaching work, such as using ICT for instructional management (Ay et al., 2015). Teachers' practical process runs through the whole process before, during and after class, which is a comprehensive description of teachers' practical traits.

The second sub-dimension is professional learning, including research, teacher professional learning, and teacher professional development. Teaching research is an important way to promote the development of education, and there are many problems and challenges in the process of integrating AI technology into the teaching system. Teachers, as teaching practitioners, can understand the problems existing in teaching based on AI teaching evaluation, and can find solutions by adjusting teaching strategies, thus improving teaching efficiency (Xu, 2021) and becoming research-oriented teachers. Professional learning and development ability is an important embodiment for teachers to update their knowledge system in time and keep pace with the times. The reform of the conventional teaching mode is aided by the employment of intelligent teaching instruments and techniques (Qu et al., 2022). AI has also changed the professional development mode of teachers, and the information they receive is constantly updated, so they should improve their own lifelong learning ability, which means to create, manage, enrich, expand and adapt to the learning ecology of teachers (Coll & Engel, 2014), and adapt to and strengthen the application of AI technology in self-development. In order to be better qualified for the teaching profession in the AI age, teachers need to improve their basic professional competence through learning (Falloon, 2020), constantly update their own ability structure with the advantage of AI technology, and develop their own ability to solve teaching or management problems (Gümüs & Kukul, 2022), and look at their learning and development from a long-term perspective.

The third sub-dimension is communication and collaboration, including empowering learners, teamwork, and international cooperation. AI can be used as a tutor or an instructor to change the relationship between teachers and students, or as a tutee or a novice learner to change the student-self relationship, or as a peer or a learning companion to change the relationship between students (Xu & Ouyang, 2021). AI has changed the way students learn and communicate, and students need more opportunities for independent development. Therefore, teachers should be willing to accept different opinions expressed by students, give students more opportunities to express and show themselves (Caena & Redecker, 2019), and promote their personalized growth. Teamwork requires teachers to obtain the ability to achieve the common expected goals with others (Peled et al., 2021). Communicative competence is a basic competence of teachers and an important part of teacher training (Zlatic et al., 2014). AI technology has changed the way people communicate with each other. Teachers' activities are mainly embodied in cooperation and communication with colleagues, classroom interaction with students, and communication with parents on teaching affairs. Therefore, teachers should have basic teamwork ability (Peled et al., 2021) to carry out effective interaction and communication with surrounding students, parents and colleagues, and efficient communication and collaboration activities with the advantage of AI technology. In addition, teachers may also have opportunities for cross-border, cross-cultural and cross-disciplinary cooperation and communication (Weng et al., 2020). Teachers have broadened their thinking in cooperation and communication, which has an important influence on their cognition and emotion, knowledge and skills.

4.3 The challenges teachers face in the AI age

From the perspective of micro ecological system theory, the challenges faced by teachers in the AI age mentioned in previous studies include upgraded teacher training requirements, a changed educational environment, the application of digital technology in teaching, and ethical issues of artificial intelligence. As shown in Fig. 7, 12 records mentioned that the upgrading of teacher training requirements has brought challenges to teachers. The training framework's comprehensiveness requires teachers to improve themselves in various aspects (Castañeda et al., 2021). The training content tends to improve teachers' innovative ability, such as innovation of the teaching mode (Koh & Chai, 2016) and the creation of digital teaching resources (Garzón-Artacho et al., 2021; Sanchez-Cruzado et al., 2021). Five records pointed out that the educational environment has changed, which has brought challenges for teachers to adapt to environmental changes. In particular, the emergence of the COVID-19 pandemic accelerated the digital development of education, and teachers need to accelerate their adjustment of teaching strategies and models to ensure the orderly progress of teaching (Peled et al., 2021; Sanchez-Cruzado et al., 2021; Tang et al., 2022). Four records mentioned that teachers have challenges while using digital technology in the classroom. In addition to effectively using digital technology in the classroom, they also need to improve students' digital skills and develop their digital literacy (Falloon, 2020; Gümüs & Kukul, 2022; Lucas et al.,
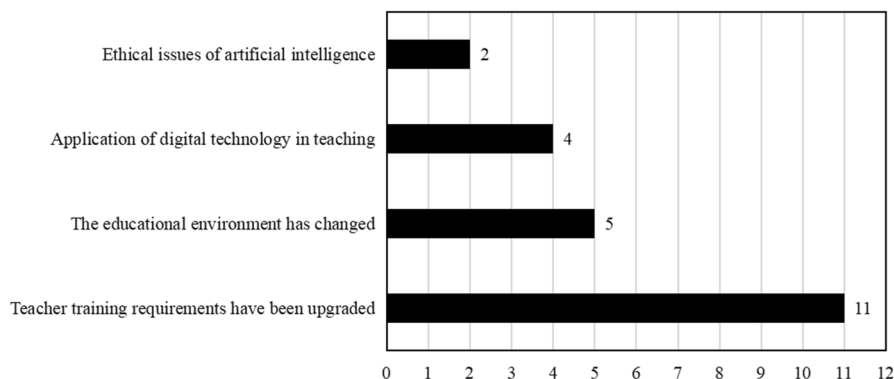
Fig. 7 The main challenges faced by teachers

2021). Two records pointed out that ethical issues of AI will become the key problem that teachers need to pay attention to in the AI age. Teachers need to have ethical knowledge to properly use AI technology and guide students to reasonably use AI technology (Celik, 2022; García & Lozano, 2021).

In the AI age, firstly, the training requirements for teachers' use of technology to enable teaching have gradually changed from imitation to creation, and from being able to use technology to effective use of technology (Prestridge, 2017). The purpose of using technology use is to be more student-centered (Hannafin & Land, 2000). Evaluation standards for teacher training are increasingly focused on the comprehensive development of teachers. Teachers need to take into account the responsibilities of multiple identities to promote their overall ability. Secondly, the outbreak of COVID-19 required teachers to quickly transfer offline teaching to online teaching (Peled et al., 2021). During the COVID-19 epidemic, the use of AI in education increased (Pantelimon et al., 2021), the educational environment changed accordingly, and the educational infrastructure equipment, teaching tools, learning tools, management tools and evaluation tools all tend to be intelligent. The change of teaching environment requires teachers to change their traditional teaching methods and quickly accept and use new teaching methods to promote normal teaching. The use of various technologies and online tools makes it more difficult for teachers to carry out teaching, and teachers need to assume new roles and responsibilities and accept new working methods (Beames et al., 2021; Pressley, 2021). Thirdly, the application of digital technology or AI technology in teaching brings challenges for teachers to design and implement teaching. Teachers need to effectively apply these technologies to teaching on the basis of learning to use them (Lucas et al., 2021), so as to improve students' digital skills (Gümüs & Kukul, 2022). Fourthly, when using AI technology to carry out teaching, ethical issues cannot be ignored. In order to ensure the development of education and instruction in the AI age, ethical issues should be paid attention to, and teachers should have knowledge and ability in this field. These challenges will further promote the teachers to equip themselves with the required competences, literacy or knowledge to adapt to teaching and learning in the AI age.

5 Discussion

Given the increasing attention to a teacher portrait for the AI age, this study summarized the traits structure of teachers in the AI age according to three aspects: knowledge, literacy and competence, and then formed a teacher portrait that meets the requirements of the times. So far, one other review has integrated the frameworks of teachers' professional knowledge, and analyzed the tasks that teachers need to undertake from the perspective of knowledge (Dijk et al., 2020). There are also reviews that provide a comprehensive analysis of frameworks related to teacher digital competency to establish standards, directions, and priorities for teacher training (Basantes-Andrade et al., 2022), and reviews that integrate frameworks of teacher educational competence to better understand teacher technological literacy in the era of artificial intelligence (Uerz et al., 2018). Differing from the above systematic literature reviews, this study comprehensively analyzed the frameworks of teachers' knowledge, literacy and competence, at least in the breadth of the framework coverage, further expanding and enriching the research results.

With the age changing from the information age, the digital age, to the AI age, based on the dimensions of the framework obtained from the review, it can be concluded that the teacher should develop new knowledge, literacy or competence with technology to facilitate their instruction in each new age. Especially, the arrival of the AI age requires teachers to have multidimensional abilities in ethics and safety, communication and cooperation, evaluation and management, and emphasizes mastering more comprehensive technological knowledge, including technological ethical knowledge, technological pedagogical knowledge, and using technology to promote the ESD. Therefore, this study highlights the ethical traits that teachers should possess, particularly in relation to the use of generative AI, such as ChatGPT (Chat Generative Pre-trained Transformer), in education. Rahman and Watanobe (2023) pointed out that educators can use ChatGPT for effective teaching and research, such as creating a course plan for a specific course, providing personalized learning support for students, and evaluating students' homework and tests by using models, but teachers need to be able to distinguish whether students use ChatGPT and prevent students from abusing or misusing ChatGPT for learning. The integration of AI and computer technology into teaching has resulted in an intelligent teaching system, providing educators with a better educational platform (Xu et al., 2022). Additionally, it allows for the analysis of students' preferences for teaching practices (Álvarez & Falcon, 2023) and the evaluation of online teaching quality using AI (Li & Su, 2020). In recent years, the emergence of the large language model is a great progress in the field of AI, which has brought great impacts and challenges to the field of education. These include potential biases in output, the need for continuous human supervision and the possibility of abuse. Therefore, teachers need to cultivate necessary competencies and literacy to cope with the challenges brought by technology (Kasneci et al., 2023). In light of this new situation, it is crucial to update the teacher portrait in the AI age. Teachers must understand the traits they should focus on to be developed in the new age.

Bronfenbrenner's (1979) micro ecological system theory highlights the significance of interaction environments and relationships, and provides a resource for drawing a dynamic and comprehensive picture of teacher professional quality (Socratous & Ioannou, 2022). Current literature on teacher development of teachers in the AI age primarily focuses on analyzing the role of AI in the education system (Xu & Ouyang, 2021). However, there is limited literature that directly reveals the structure of teachers' abilities in the AI age. This study makes a significant contribution to describe the teacher portrait in the new age. Furthermore, guided by the PPC model theory, the elements of a teacher portrait are closely interconnected and form a cohesive and integrated whole. Other similar studies have discussed teacher portrait from different views. Ally (2019) identified nine main areas of responsibility for future digital teachers. They include general, use digital technology, develop digital learning resources, re-mix learning resources, communication, facilitate learning, pedagogical strategies, assess learning, personal characteristics. The area of responsibility are included in the teacher portrait in this study. Jacobs et al. (2014) classified teacher profiles into five categories by clustering: transmitters, organizers, intermediaries, facilitators and conceptual change agents, the elements of teacher portrait in this study are identified in the traits of these different roles.

In addition to the teacher portrait framework for the AI age, we also analyzed the challenges faced by teachers in the AI age based on the micro ecological system theory, and found that teachers are mainly faced with four challenges, namely the ethical issues of artificial intelligence, the upgrading of teacher training requirements, the application of digital technology in teaching, and the change of educational environment. This was also confirmed by a similar study, which pinpointed that AI technology brings challenges to education in terms of data privacy and teachers' acceptance of AI (Chen et al., 2022). In addition, it has been confirmed in another study, which pointed out the challenges teachers face in effectively and ethically using AI technology (Crompton et al., 2022). These challenges help teachers understand the difficulties to overcome to achieve development in the AI age; that is, teachers need to liberate their own labor force in combination with AI technology in order to be more competent in teaching. Teachers also need to have the ability to adjust to the changes in educational environment, and should use AI technology to reasonably promote teaching. Moreover, they need a strong sense of ethics and prevention ability. Thus, it expands the outline of the teacher portrait framework for the AI age. These findings stem from a review of the body of research on teacher frameworks and therefore reflect a broad consensus on the frameworks and challenges of the teacher portrait for the AI age.

6 Conclusions

The urgent discussion of what teachers should be like in the AI age is the focus of this study. The frameworks of teachers' knowledge, literacy, and competence were systematically reviewed, and a teacher portrait for the AI age was constructed based on the PPC model. The study found that teacher frameworks with digital and

intelligent features can be used to construct a teacher portrait in the AI age. Based on the frameworks, the teacher portrait in the AI age is constructed to consist of three dimensions and eight sub-dimensions: teachers' cognition and emotion, teachers' knowledge and skills, and interaction between teachers' cognition and ability. Further, the challenges faced by teachers in the AI age include upgraded teacher training requirements, a changed educational environment, the application of digital technology in teaching, and ethical issues of artificial intelligence. These conclusions can provide guidance for the development of teachers in the AI age.

6.1 Implications

Theoretically, in the face of the impact of the application of AI technology on the field of education, the education system has undergone structural changes (Zmyzgova et al., 2020). As teachers are implementers of education in the education system, the corresponding teacher competency structure should be adjusted accordingly. In order to cope with the challenges brought by the application of AI technology by teachers in teaching, this study combined the common traits of existing frameworks and proposed a teacher portrait for the AI age according to micro ecological system theory: person, process and content. This study makes corresponding adjustments to the teacher portrait from three perspectives: teachers' cognition and emotion, teachers' knowledge and skills, and the interaction between teacher cognition and ability in the AI age. The aim is to help teachers maintain their unique advantages of teachers in the face of AI technology. This framework's primary goal is to offer a system structure for constructing a teacher portrait, so as to realize the automatic evaluation of teachers' traits and the personalized improvement of teacher development.

In addition, from a practical viewpoint, the framework is rich in added value. It can be adapted into questionnaires, scales or self-assessment tools to evaluate teachers' development level, so as to provide educational researchers with an effective means of data collection. Comprehensive data can be collected on teachers' development levels, and systematic and scientific research can be conducted. This can provide measurement tools for educational administrators to implement interventions in teacher development. Through this, problems in teacher development can be identified and targeted intervention measures can be inplemented to achieve the comprehensive promotion of teachers. In addition, the framework can provide targeted guidance for teachers to improve their individual levels. They can reflect on the relevant traits they have and the traits they will develop in the future, and constantly improve themselves with the traits of teachers in the framework as the target.

6.2 Limitations and future study

This study mainly analyzed and synthesized frameworks that could be used to construct a teacher portrait from the micro ecological system theory perspective, and the results were also derived from existing studies. Therefore, it has high requirements

for the authority of data sources, the standard of data screening, and the comprehensiveness of data analysis. First of all, the data of this study mainly came from three databases, and a literature search was conducted according to the identified keywords. Secondly, this study finally built a teacher portrait to provide directional guidance for teacher development in the AI age. The description of the portrait need to include more practical characteristics. The teacher portrait should have a visual representation of teacher traits and provide explicit information to demonstrate that teachers meet relevant requirements. Therefore, the practical application of the framework should be further refined and adjusted in combination with specific practical scenarios.

To address the research deficiencies mentioned above, future studies could expand their data sources beyond journal literature to include teacher frameworks mentioned in books or policies. This would enhance the credibility and value of the final research results. Future research should also pay more attention to the realization and application of the teacher portrait, and the feasibility of its realization while constructing the framework, highlighting not only the theoretical value of the framework, but also its practical value.

Data availability The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interests Not Applicable.

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