frontiers | Frontiers in Education

TYPE Review
PUBLISHED 31 March 2023
DOI 10.3389/feduc.2023.1161777

OPEN ACCESS

EDITED BY
Alona Forkosh Baruch,
Levinsky College of Education, Israel

REVIEWED BY
Tak-Lam Wong,
Douglas College, Canada
Rosanna Yuen-Yan Chan,
The Chinese University of Hong Kong, China

*CORRESPONDENCE
Giuseppe Città
✉ giuseppe.citta@itd.cnr.it

SPECIALTY SECTION
This article was submitted to Digital Learning Innovations, a section of the journal Frontiers in Education

RECEIVED 08 February 2023
ACCEPTED 09 March 2023
PUBLISHED 31 March 2023

CITATION
Gentile M, Città G, Perna S and Allegra M (2023) Do we still need teachers? Navigating the paradigm shift of the teacher's role in the AI era. *Front. Educ.* 8:1161777. doi: 10.3389/feduc.2023.1161777

Do we still need teachers? Navigating the paradigm shift of the teacher's role in the AI era

Manuel Gentile, Giuseppe Città*, Salvatore Perna and Mario Allegra

Institute for Educational Technology, National Research Council of Italy, Palermo, Italy

Through a systematic analysis of the literature, this study analyzes the change in the teacher's role triggered by the integration of AI into educational systems. The picture offered by the systematic analysis of the literature conducted in this study reveals a less than total awareness of the urgency with which the challenges imposed by AI in the educational field must be addressed. We propose a manifesto to guide the evolution of the teachers' role according to the paradigm shift concept proposed by Kuhn in the scientific field.

KEYWORDS

AI and education, paradigm shift, teacher's role, AIED, AI, ChatGPT

1. Introduction

Technological "evolution" has always influenced the world of education by providing new opportunities and challenges for those who form such a foundational part of it as schools and their key players such as teachers and school leaders, students and families.

The new "renaissance" (Tan and Lim, 2018) that AI has been experiencing in recent years, generated by innovations related mainly to deep learning, has stimulated discussion on how advances in AI can influence the educational sector and future educational policies.

In 2018, the EU published a JRC Science for Policy report entitled "The Impact of Artificial Intelligence on Learning, Teaching, and Education" to initiate a well-informed discussion about the state of the art of artificial intelligence (AI) and its potential impact on learning, teaching, and education (Tuomi et al., 2018). Creating a future vision that integrates a careful understanding of our values in education is the key to identifying the contexts in which educational policies could and should intervene.

As indicated in the recent UNESCO report "Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development," the integration of AI in education raises several questions (Pedro et al., 2019).

According to the report "Beijing Consensus on artificial intelligence and education," some of the crucial issues are the need to dynamically review and define teachers' roles and required competencies in the context of teacher policies, strengthen teacher training institutions, and develop appropriate capacity-building programs to prepare teachers to work effectively in AI-rich educational settings.

There is a need to deepen the reflections on the transparency of decision-making processes of AI systems that extends the discussion on ethical issues related to the massive collection of students' data (Miao et al., 2021). Integrating AI techniques into educational processes requires further investigation into the issues of the "digital divide" and social inclusion, the risks associated with such innovations, and the opportunities that technologies offer for handling these issues with new approaches. Above all, a reflection is also needed on

the role of teachers, what skills they should have, and what tools to provide them with to make them conscious actors in these innovation processes.

Starting from the first works that introduced the concept of Artificial Intelligence and Education (AIED) (Cumming et al., 1997; Cumming, 1998; Kay, 2012), several review works have been conducted to offer a systemic view of this phenomenon. The work of Chassignol et al. (2018) analyzes the literature under a four-dimensional framework (content, teaching methods, assessment, and communication) to study the impact of AI in education. The study from Kuka et al. (2022) is a scoping review of where and how AI is used in higher education learning and teaching processes. Another example is the exploratory review of Lameras and Arnab (2022) in which the authors explore the ethical implications of using AI in the educational context, how these technologies can enhance the role of the teacher are discussed, and the applications used and associated teaching and learning practices.

Numerous other reviews on the topic of AI in Education can be found in the literature (e.g., Moreno-Guerrero et al., 2020; Yu and Nazir, 2021; Abdellatif et al., 2022; Dieterle et al., 2022; Megahed et al., 2022, etc.). In addition to the scientific literature, recent books such as Holmes et al. (2019) and Holmes and Porayska-Pomsta (2023) analyze the changes introduced by AI in education.

Of course, these issues are still being also debated in the scientific arena, where a steady increase in studies linking AI and education is evident (Floridi et al., 2018; Holmes and Tuomi, 2022).

Nevertheless, from our point of view what is missing and what prompted us to produce this paper is the need to focus analytically on the paradigm shift in the role of the teacher introduced by the AI era.

Teachers have always been called upon to change their teaching approach by attempting to integrate new technology rather than rejecting it out of hand. However, even at first glance, the potential changes introduced by AI signal a radical change, what can be called a genuine paradigm shift. Therefore, this paper aims to provide a systemic view of this revolution, not by simply offering an overview of the various AI-based tools already available but by trying to grasp the profound changes in the role of the teacher the AI may trigger.

The paper is structured as follows. In Section 2, we discuss the approach used to carry out the review, particularly concerning the choices in defining the search query and coding scheme. Subsequently, in Section 3, we present the results from a general point of view and in detail for each analysis dimension. The paper closes with a discussion that provides a summary of the results and a proposed manifesto to guide the change of the teacher's role in light of the parading shift concept proposed by Kuhn (1962).

2. Materials and methods

The study was done according to the Preferred Reporting Items for Systematic Reviews and Meta-analyzes reporting guideline (PRISMA Checklist) (Page et al., 2021). The search was conducted by accessing the main bibliographic databases such as Web of Science, Scopus to which we have added the ACM Digital Library (DL) to include as much as possible the literature covering computing and information technology.

The research query consists of three main parts. The first lists the terms that allow us to identify the context of artificial intelligence. In particular, we have included both the general terms AI (in contracted and extended form), and the terms machine learning and deep learning, which are often used as synonyms or otherwise identify items of interest for this review. In addition, we have added the extended and contracted form of natural language processing because of the extreme relevance the topic may have in the AI and education field (Litman, 2016). The second group of terms relates to the specific teaching context, where we have included the main aspects of expertise or interest for teachers and teaching processes. Finally, the third group seeks to identify those articles that signal a change, an evolution of the role. Finally, the research focuses on articles published since 2005, a significant date because it identifies the beginning of what has been called the renaissance of AI and coincided with the bursting onto the scene of deep learning.[1]

A clarification is due regarding the absence of the term AIEd (AI in Education, Holmes et al., 2022) among those used within the queries. In the context of our study, we preferred not to limit the analysis to that portion, albeit relevant, of AI that looks explicitly at the educational context identified with the term AIEd (Holmes et al., 2022). Instead, we wanted to analyze the impact of AI in general on the role of the teacher.

In the following box, we report the query used to search the Scopus database. We adapted the query syntax according to the formalism required by each database.

```
TITLE-ABS-KEY
(( "ai" OR "artificial intelligence" OR
 ↪  "deep learning" OR "machine learning"
 ↪  OR "natural language processing" OR
 ↪  "nlp" ) AND
( "educational process" OR "teaching
 ↪  practices" OR "teaching methods" OR
 ↪  "teaching approach" OR "teaching
 ↪  solution" OR "teaching design" OR
 ↪  "teacher development" OR "teaching and
 ↪  learning" OR "pedagogical methods" OR
 ↪  "teacher's role" OR "teachers role" )
 ↪  AND
( transformation OR "new role" OR evolution
 ↪  OR change OR revolution OR enhance OR
 ↪  "paradigm change" OR "paradigm shift"
 ↪  )) AND PUBYEAR > 2005
```

The following inclusion criteria were used for each study: (1) published in English; (2) the study must illustrate, discuss, or theorize the teacher's role in the AI era or must report a study of classroom use if it introduces new AI-based educational practices. Studies that discuss education about AI or studies of articles that discuss only technological and not pedagogical aspects have been excluded.

1 In 2005, the first paper combining the words deep and learn in the title was published (Gomez and Schmidhuber, 2005).

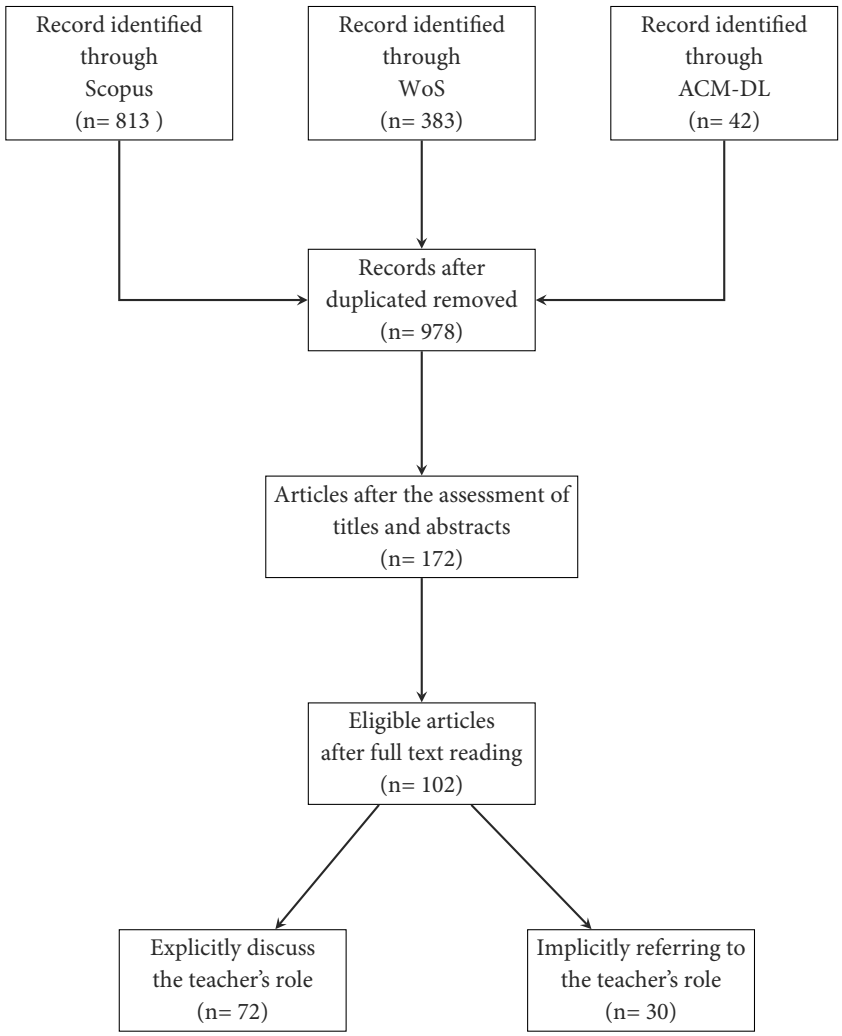

FIGURE 1
Summary of the systematic review process

We searched independently in each database and exported the results in BibTeX format. JabRef software (JabRef Development Team, 2021) was used to merge the three lists and remove duplicates. Subsequently, three reviewers (MG, GC, and SP) independently screened the articles by assessing the articles' titles and abstracts to remove elements inconsistent with the review objective. As shown by Figure 1, this phase led to a drastic reduction in the number of papers (806 papers excluded, amounting to 82.41% of the initial pool). Then the reviewers analyzed the remaining 172 papers by reading the full text and extracting the following information:

1. Year of the publication;
2. Type of the publication;
3. School level;
4. Presence of discussions concerning any of the following topics:

   - Teacher-student interaction
   - Teaching methods and strategies
   - Teaching content
   - Students' assessment and monitoring
   - Teachers' professional development

We identified the topics of investigation (see Figure 2) linking (i) the set of qualities that characterize the teachers' professional development challenges according to Stone Wiske et al. (2001) and (ii) the constituent dimensions of a teaching system identified by Huang et al. (2021).

First, reducing the student-teacher proportion toward the utopian goal of one-to-one interaction has historically been one goal that has driven the implementation of AI systems in the educational sector. In addition to this underlying objective, the first area allows us to explore all the new monitoring and interaction management scenarios AI provides.

Regarding teaching strategies, the innovation challenge of teaching and learning activities connected to integrating new technology into the educational landscape is even more prominent if we consider AI's exponential growth.

AI also impacts the educational content either regarding the need for new professions revolving around the world of AI, as well as considering the possibilities of such techniques to

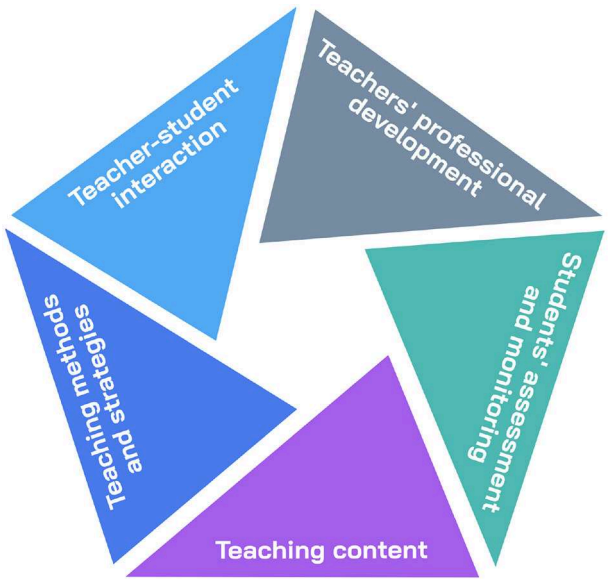

FIGURE 2
The adopted framework of analysis.

support the creation of *ad-hoc* content customized to the needs of learners.

Moreover, the assessment-centered approach is one of the critical goals of professional development in the AI era. AI allows for overcoming the limitations of the traditional summative assessment, making it feasible to move toward continuous formative assessment fully integrated into the teaching process.

To summarize, teachers need professional development opportunities that support them in the transformational process and satisfy these needs.

The reciprocal integration of these dimensions and, consequently, of the elements that are part of each of them makes it possible to look at a teaching system as a whole whose components work coherently. Researching and analysing these dimensions within the papers has meant activating a critical view of the effect of AI on the building blocks of the complex education system.

At the end of the process, 102 papers were considered eligible for review, of which 72 explicitly discuss the teacher's role and 30, while lacking explicit discussion, provide valuable insights for the scope of the review.

3. Results

From the analysis of the selected articles, it emerges that the application of AI in Education is operating and will increasingly operate profound changes on the constitutive pillars of the educational system and on the role the teachers play in it. The trend of annual publications on the study topic shows exponential growth and increasing interest in the scientific community (see Figure 3). The Table 1 shows an even distribution among the dimensions of analysis covered by the articles.

The distribution by country emerging from the analysis of the selected articles shows an interesting result. As highlighted by Figure 4, about half of the articles come from China, sketching a huge gap already with the second country, the United States of America. This gap demonstrates a particular focus of Chinese research concerning the subject matter of this study, namely the analysis of the role of the teacher from the perspective of integrating AI in education.

3.1. Teacher-student interaction

The relationship between teacher and learners, with the interactions that arise and develop within it, is one of the most critical elements in the context of the educational paradigm. The literature analyzed extensively highlights how technological developments, in particular the advent of the artificial intelligence era, have profoundly challenged the teacher-student-teacher interaction models to which we are accustomed.

In the context of the traditional educational paradigm, interactions between teacher and student are predominantly individual, and the moments of feedback and assessment are limited and timed according to the topics covered by the curricula (Liu M. et al., 2022). Within this context, one of the most crucial moments of interaction and feedback is precisely that which takes place simultaneously as the evaluation of the student's performance, which typically follows the presentation of the topics. The classroom setting implicitly forces the teacher to postpone interactions with individual students, but this makes it particularly difficult to assess the effect of his or her teaching and the status of the individual difficulties presented by the various students.

After all, within the traditional educational model, the teacher represents the authority, and the relationship between teacher and learner is hierarchical (Ye, 2021). The transfer of knowledge often occurs in a non-participatory and non-interactive manner and is seen as pouring from a full container into an empty one. Students, inherently characterized by individual needs and peculiarities, are often categorized within families of "similar elements" with the result of standardizing education in a convergent manner to the detriment of its effectiveness. This type of relationship tends not to foster collaboration between teacher and students and, in extreme cases, can lead to negative effects such as absenteeism and dropout (Li, 2021).

The literature shows that, among the elements introduced by the AI era with the most significant impact on the way teachers and learners interact, one of the most important is that of Intelligent Tutoring Systems (ITS). These systems are designed to interact with students and provide them with tutoring intelligently and automatically. They collect data on students' responses and actions to create a model of their knowledge and adapt to their needs. In this way, ITS manage to create a digital profile of the student and provide them with a personal tutor (Chassignol et al., 2018). This feature often leads to the erroneous conclusion that these systems can completely replace the teacher's figure. Although ITS can help enormously in implementing adaptive and personalized teaching and learning strategies, they are not a substitute nor an obstacle in the relationship and interactions between teacher

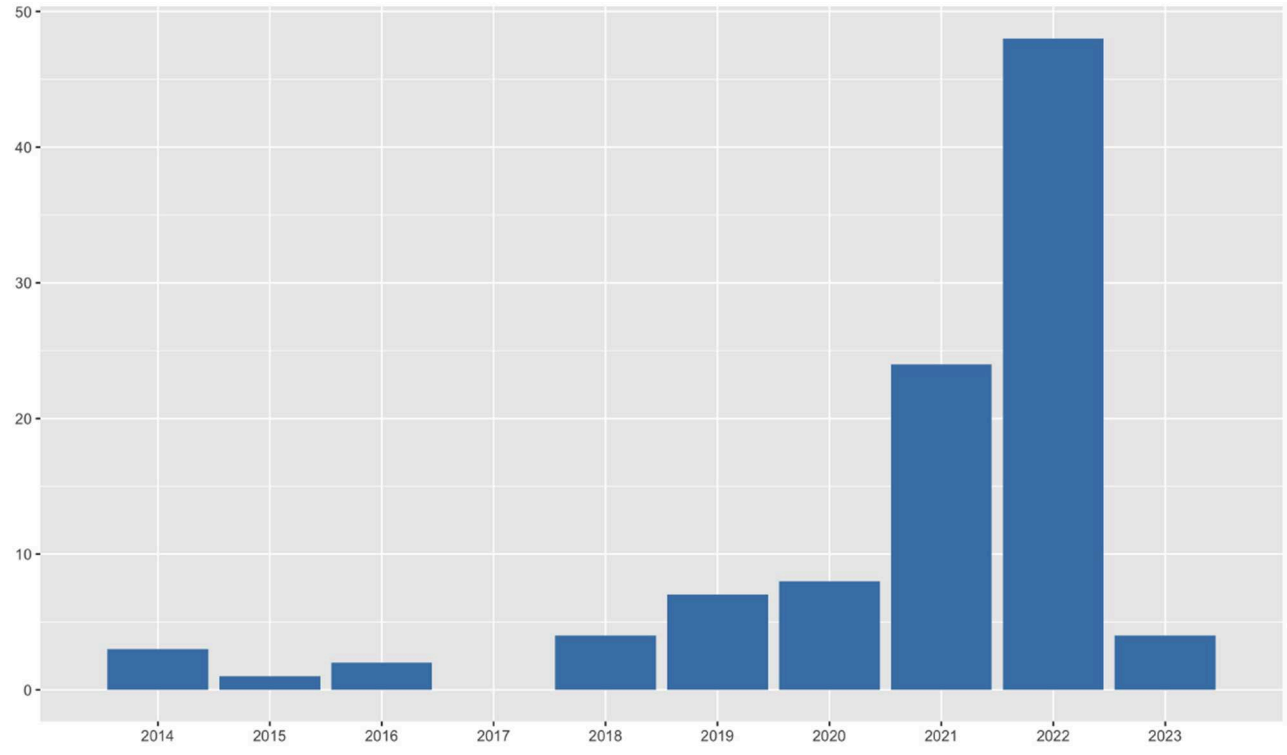

FIGURE 3
Distribution of papers by publication year.

and learners. On the contrary, they can be an essential support tool for the teacher to save valuable time in executing tasks like assessing large numbers of students and presenting teaching materials and resources. Moreover, ITS could provide them with the opportunity to increase the quantity and quality of interactions with students and consequently to identify gaps in learning and teaching at an early stage (Chassignol et al., 2018; Miao and Yao, 2021). Teachers can use the information gathered through ITS to accurately diagnose differences between students and use it to recommend customized and suitable resources (Li, 2021).

Similarly, chatbots and robots can take over most of the interaction related to content and teaching materials and resources (Megahed et al., 2022; Timofeeva and Dorofeeva, 2022; Zhou, 2022). They can automatically answer the most frequent or repetitive questions, enhancing interactions with the teacher and allowing them to become more connected to students' learning strategies and individual needs.

The continuous technological advancements in natural language processing (NLP), which have led to results such as ChatGPT (OpenAI, 2021), only further strengthen the effectiveness of AI-based tools in communicating and interacting with students. Although Artificial Narrow Intelligence (ANI) is making rapid progress (Johri, 2022) and several studies prove the effectiveness of those systems in providing knowledge in various fields (Chassignol et al., 2018; Li, 2021; Su and Yang, 2022), the human teacher remains (to this day) irreplaceable.

Specifically, the human factor is an irreplaceable characteristic of the teacher. The teacher is a guide and reference for students' growth and a compass for their ethical and moral development. In this sense, these tools, which at first glance seem antagonistic to the teacher, are facilitators of the quality interactions that characterize the teaching process.

TABLE 1 Number of papers discussing the coding schema dimensions.

Coding schema dimensions	Number of papers
Teacher-student interaction	37
Teaching methods and strategies	33
Teaching content	27
Students' assessment and monitoring	29
Teachers' professional development	22

Another element explored in the literature that may be complementary to the systems discussed above is the smart classroom (Zhang, 2014; Kowch and Liu, 2018; Zhang Y. et al., 2021; Dimitriadou and Lanitis, 2022, 2023; Liu M. et al., 2022). Although integrating technology within the classroom environment is not a new idea (Rescigno, 1988), constant technological advances in AI have given the idea more and more traction.

A smart or future classroom is intended as a highly integrated environment with sensors and devices capable of automatically controlling and acting on environmental factors (such as temperature and lighting), enhancing communication and real-time interactions both between students and between students

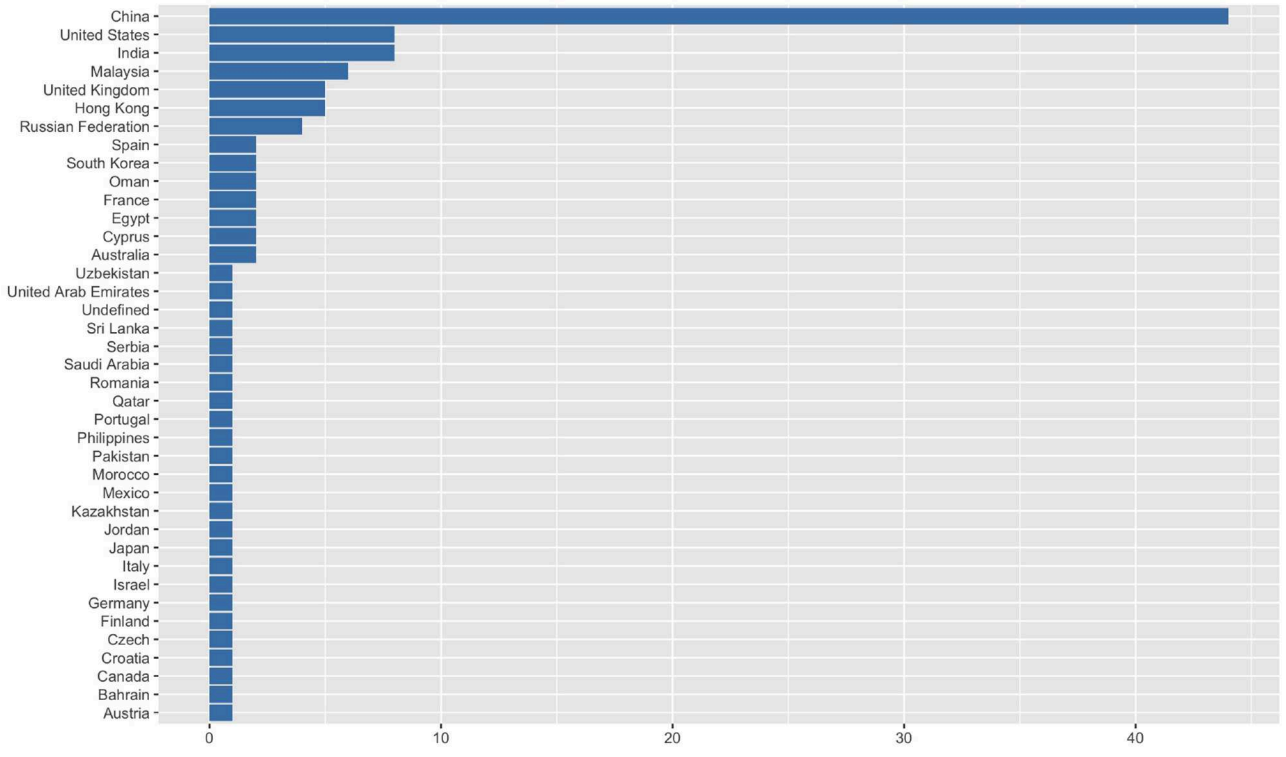

FIGURE 4
Distribution of eligible papers by country.

and teachers (by fostering inter-group collaboration and resource sharing), and overcoming the boundaries and limitations offered by the traditional classroom environment through the Internet and the cloud.

In particular, through the use of Artificial Intelligence of Things (AIoT) and wearable devices, it is possible to capture and monitor students' and teachers' behavioral data in real-time (Zhang Y. et al., 2021; Dimitriadou and Lanitis, 2023). Furthermore, through electronic whiteboards, it is possible to introduce and utilize different types of educational resources that are often difficult to use and present within the traditional classroom context. Another application of smart classroom opportunities is the use of visual feedback (obtained through cameras) to monitor students' attention and emotional state. Through the devices used, it is possible to harness the power of AI to check students' status (both in presence and remotely), obtain real-time information, identify problems related to individual students, and intervene promptly. Despite the countless opportunities and substantial benefits offered by this type of environment, it is nevertheless essential to carefully consider the ethical consequences of such data collection (Dimitriadou and Lanitis, 2022). The learners' (and teachers') right to privacy and security requires a careful evaluation of the data collection, storage and processing protocols. In addition to the costs associated with these types of devices and environments, the delicate nature of data processing and collection can be a strong deterrent for the stakeholders involved. Moreover, the current state of machine learning and AI models does not allow us to exclude potential biases and errors related to false positives (Johri, 2022). This implies that teachers must be able to deeply understand the functioning mechanisms of these systems in order to be able to recognize errors and act in an efficient manner that serves the teaching and pedagogical objectives.

An interesting observation concerning the change in the interactions brought about by AI is that provided by Johri (2022). In his work, the author approaches the topic from a socio-material point of view (Orlikowski, 2002, 2008; Latour, 2007; Suchman and Suchman, 2007; Orlikowski and Scott, 2008; Sørensen, 2009), in which the learning process is strongly dependent on both the social and the material context in which it takes place. According to Johri (2022), the impact of AI on the processes and role of humans within learning practices is fundamentally different from the one technologies had until now. The central element of discontinuity stands in the ability of AI to provide technology with the power and agency to initialize interactions, configuring itself as a communicator on par with the human (Edwards, 2021). The evolution led by AI represents a disruptive change with respect to how we have constructed the concept of agency in the past through social interactions. In this AI era, human-machine communication becomes bi-directional and, above all, can be initiated by both actors. Notifications, alerts and automatic messages are examples of this phenomenon. Technology, which until now has always played a material role, is becoming an agent in its own right. Considering large learning models' rapid innovations and achievements in producing original resources and contents, both textual (OpenAI, 2021) and audiovisual (Ramesh et al., 2021; Singer et al., 2022), it is easy to see how much these communication skills will improve in the future.

In the context of the relationship between teachers and learners, the innovations and disruptions conveyed about by AI are numerous and act at a fundamental level. The primary transformation is about the roles within this relationship. Teachers must learn to become collaborators, mentors and guides of their students (Wang C, 2021; Khusyainov, 2022; Tapalova and Zhiyenbayeva, 2022). Interactions, until now often driven by the concept of authority, must acquire a different character, more driven by symbiotic and increasingly equitable dialogue (Li, 2021), to transform authority into authoritativeness.

AI provides the opportunity to uncover new occasions of interaction, both synchronous and asynchronous, that are freed from the timing and structure of traditional school organization and can focus on those factors that make a person a teacher. These new moments and modes of interaction can be an essential catalyst for implementing proper educational pathways tailored to the needs of individuals. Teachers must cultivate students' passion for learning, ability to think critically, and ability to navigate the sea of information and educational resources surrounding us.

Rather than identifying AI as an antagonist, educators must learn to coexist with it, moving from a binary (student-learner) to a ternary (student-machine-learner) relationship in which interactions are mediated, modified, and sometimes initiated by technology in a way that is enhanced, rather than diminished.

3.2. Teaching methods and strategies

Regarding the methods and strategies implemented by teachers in educational processes, the main contribution of AI relays the shift in the center of gravity of teaching processes and models: from teacher-centered models and processes to learner-centered models and processes (Hou, 2020). This does not mean that the teacher's figure has been given a back seat. It means, instead, that with the advent of AI, this figure, given the current state of the teaching strategies implemented, is invested by profound changes that we will try to explain with the help of the literature analyzed.

The key component that emerges from the examination of the papers is commonly expressed through the expression "personalized learning" (Chassignol et al., 2018). Students' learning rhythms are not standard and the same for all, just as the prior knowledge of each student and the issues related to each course of study are heterogeneous (Ye, 2021). By action of the AI, the personalization of learning paths produces tangible effects on students' learning processes, and this is by an almost revolutionary reconfiguration of the teaching strategies and methods implemented by teachers (Su and Yang, 2022). With the help of tools and techniques such as smart platforms, big data, cloud computing, machine learning, and natural language processing (Litman, 2016; Asgari and Antoniadis, 2021; Liu M. et al., 2022; Liu Y. et al., 2022; Megahed et al., 2022; Dimitriadou and Lanitis, 2023)the teacher can implement comprehensive student monitoring. Thanks to these tools, the teacher is able to collect, represent and analyze in-depth data on students' learning behavior, their learning attitudes and styles, the educational needs of each student and the mutual differences between personal learning paths. Placed in this context, the teacher becomes the actor who, as the first step in an educational pathway, does not introduce knowledge content to the students but possesses the elements to elaborate learner models for each student (Ye, 2021; Yusupova et al., 2022; Dimitriadou and Lanitis, 2023).

The teacher who has this knowledge available should reflect on the strategies and methods used to date and those that are more appropriate today. While in a classical scenario without the contribution of AI, teachers tend to assign the same tasks, lessons and tests to all the students, in the AI era, the teacher can focus on designing innovative ways of teaching. Teachers no longer focus on transmitting homogeneous knowledge contents and designing assessment modalities to verify whether the student has assimilated those specific contents (see Section 3.3) (Liu Y. et al., 2022). In the AI era, the teacher can focus on promoting students' skills like collaboration, autonomy, exploration, problem-solving and creativity. Elements that machines cannot yet emulate (Miao and Yao, 2021). In essence, it is the case that the teacher can be freed from many of the activities that students used to perform and that required his or her help, if not his or her presence: correcting homework, vocabulary training, composing tasks to train numeracy skills, writing, answering frequently asked questions, organizing activities in time. Now, the teacher's work can entirely focus on understanding each student's abilities and level to design targeted teaching paths with the ultimate aim of stimulating the students' personality, self-esteem and potential (Wang C, 2021).

Thanks to the contribution of AI, the teacher of the future will have to focus on the following objectives: cultivating the individual development of students; designing interactive and open teaching even at a distance (in time and space) through the combination of virtual and physical environments; fostering the development of students' autonomous learning, growth and ability to express themselves; considering the flexibility of teaching activities the norm and not the exception; giving particular emphasis in teaching design to the cultivation of the so-called students' 'non-intelligence factors' (the moral character, intelligence, sporting dimension and artistic dimension) (Liu and Wang, 2020; Caijun et al., 2021; Huang and Gupta, 2022). The full realization of the aims mentioned above represents a future of teaching strategies, even if they have already been pursued in numerous educational contexts combined, in some cases, with gamification techniques (e.g., rankings and prizes) and the use of robotic platforms (Vogt et al., 2019) to collect and analyze students' progress and offer the most functional strategy/tool also taking into account any disabilities (Chassignol et al., 2018).

Another essential element that emerged from the literature analysis concerns the extension in time and space of the actions and strategies the teacher can implement thanks to the use of AI. AI allows teachers to characterize their work according to the specific time and space they occurred (before, during and after class) (Yang, 2022). Tasks like the analysis of students' profiles, the design of learning pathways and activities, the organization of assessment sessions and modes in a flexible manner and structural coupling with the environment will assume specific flavors according to the specific timing and place in which these events are to take place. In other words, the teacher has, for the first time, the opportunity to design, develop and implement a systematic teaching model that accompanies the individual learner's learning and personalized

pathways in space and time that goes beyond the classroom environment. Liu Y. et al. (2022) express very clearly this "new" possible scanning of learning paths. The authors highlight how, in a before-class context, learning tasks can be assigned in advance to individual students through a smart platform and how this operation allows the student to explore and study tasks in advance, ask questions or raise doubts. All of these actions can be collected and analyzed by the teacher as feedback data *via* a smart platform and, consequently, used to calibrate individual learning paths to the student's traits and level of knowledge or to modify the design of the entire teaching proposal. Such a range of possible actions clearly also has repercussions on the strategies and methods put into practice in the context of in-class teaching. They are expressed into the possibility for the teacher to design refined teaching: introduction of the topics to be studied in a contextualized manner, active guidance of the student in the exploration of the problems and difficulties recorded in the 'before-class' context, targeted brainstorms on specific topics emerging from the feedback data. The teaching model becomes systematic by implementing specific activities in the 'after-class' context. Within this context, the teacher can pose open questions based on the feedback from the two previous contexts, assign tasks individually based on learning status, and conduct online tutoring sessions to guide each student to summarize and subsume their learning.

An excellent overview of how much AI can impact, and how much it will impact in the future, on teaching strategies and methods is given by Lameras and Arnab (2022). According to them, AI represents a concrete possibility to: (a) support teachers to design adaptive and personalized content and activities appropriate to the knowledge, competence and needs of students, (b) empower teachers and AI agents to collaborate in collecting and analysing student learning and cognitive feedback data, (c) help teachers to step into the shoes of tutors of students' emotional awareness and cultivators of each student's social and affective learning.

3.3. Teaching content

The extent of the changes brought about by the advent of AI is also noteworthy in the production and delivery of teaching content in all educational contexts and at different levels of complexity (Liu and Wang, 2020; Wang C, 2021). The term "teaching content" refers to the body of knowledge and information that teachers teach and that students are expected to learn within a given domain of knowledge (Chassignol et al., 2018). According to Huang et al. (2021), teaching content comprises the knowledge, skills, thoughts and behaviors transmitted by the school to students at all levels.

From the literature analysis, day by day, thanks to the new possibilities offered by AI, new and different types of educational resources and new ways of generating them emerge (Bucea-Manea-oniş et al., 2022; Khusyainov, 2022; Niu, 2022). It is precisely in this direction that "Content Intelligence," a discipline-specific to AI, until now applied to marketing automation, is beginning to operate in the field of education. It opens up the possibility of organizing content and, at the same time, extracting real-time indications on the navigation behavior, fruition and preferences of students in order to implement a customized educational offer.

As emerged in the previous Section 3.2, also in the context of teaching content, personalized learning emerges as the primary effect produced by the action of AI in the educational sphere. This effect disrupts the traditional ways of conceiving, processing and proposing teaching content. Within a conventional didactic approach, teaching contents are the same for all students and static, defined as "closed" because they are hardly modifiable (Ye, 2021; Lameras, 2022). They are organized to be learnt linearly and progressively. According to Hao (2022), the advent of customization makes obsolete the one-way knowledge transfer approach from teachers to learners. It gives way to a focus on the personalized learning processes of students, enabling teachers to organize teaching content that enhances learners' sense of personal fulfillment and helps them learn autonomously. In this perspective, teaching content in general and learning resources in particular change form, structure and how they are generated (Shuguang et al., 2020; Nye et al., 2021).

Thanks to the contribution of the AI, teaching contents move to a new formula in which courses and possible reference texts are accompanied by *ad-hoc* created digital resources and resources from the Internet. These resources can, through machine learning and deep learning, be organized in a multimodal manner and divided into a series of smaller resources that are more manageable and adaptable to the different needs of students. Precisely because of their new multimodal character, they cannot be structured in a monolithic form but must be organized as cross-media and flexible structures so that they can be adapted to the abilities, levels and needs of individual learners. Therefore, contents change starting from their generation process: no longer a static and homogeneous generation but a dynamic and customized one. A generation that makes them dynamic contents of intelligent learning systems that provide personalized paths to the students (Shuguang et al., 2020).

It appears from the analysis of the papers that the trait of personalization of teaching content introduced with the advent of AI means that they acquire new related identifying characteristics. The "new" teaching content will be flexible, manipulatable, explorable, and automatically generated.

They will have flexibility and manipulability as a direct consequence of a personalized teaching approach. The creation of teaching content in an AI context contemplates the need to construct content that can be constantly modified, enhanced, revised and integrated to create original structures perfectly adaptable to the learner's different needs. In this regard, the in-depth examination of the selected papers reveals several examples of the implementation of the flexibility and manipulability features of the teaching content with the help of specific tools and/or teaching strategies. It is crucial that the teaching content be designed in such a way that (a) it can be used by students autonomously through libraries and corpora (e.g., cloud classroom libraries), (b) can be explored collaboratively (Dai, 2021) and continuously (Wang D, 2021) and (c) can be generated and managed automatically according to defined learning objectives (Liu Y. et al., 2022; Schroeder et al., 2022) through specific tools such as automatic question generation tools (Van Campenhout et al., 2021), video content generation tools (Zhang Z. et al., 2021), analytics-based platforms (Conklin, 2016), cloud service solutions or algorithm-based platforms (Alsheref and Fattoh, 2020), e-learning platforms (Khan et al., 2022), natural language processing

and image processing techniques (Sandanayake and Bandara, 2019).

Moreover, the study of the literature reveals that the traits of personalization, flexibility, manipulability, explorability and automatic generation triggered by AI are structural traits of the teaching content of the AI era. For this reason, they are transversal to the single disciplines to which the simple learning contents can be attributed. The analysis of the case studies contained in the analyzed papers reveals a broad distribution across the different fields of knowledge: Anatomy (Abdellatif et al., 2022), Proportional Reasoning (Nye et al., 2021), English and other foreign language teachings (He, 2021; Faustino and Kaur, 2022; Liu and Huang, 2022), Microbial Metabolism (Schroeder et al., 2022), Psychology (Schroeder et al., 2022), Interior Design teaching (Cao and Li, 2022), Social Work Education (Hodgson et al., 2021), Engineering Education (Megahed et al., 2022), Music Design (Dai, 2021), Scientific Writing (Kim and Kim, 2022), Programming Languages (Yusupova et al., 2022), and Translation teaching (Yang, 2022).

3.4. Students' assessment and monitoring

The use of AI in educational assessments is a prominent field of application, and its integration into this process has been extensively studied and discussed in the literature. Assessment is considered a fundamental step in evaluating the impact of AI-powered teaching methods (Luckin et al., 2016). According to the review study conducted by Salas-Pilco et al. (2022), AI and Learning Analytics (LA) techniques have the potential to assist teachers in several activities. Moreover, several studies show that in the teachers' perceptions, AI potentially impacts the evaluation processes. For example, Bucea-Manea-oniş et al. (2022) conducted a study on 139 Romanian and Serbian teachers in HEI, revealing that using AI technologies to assess homework, tests, written assignments, and general student monitoring is an opportunity for them (Bucea-Manea-oniş et al., 2022).

Many of the selected articles in our review refer to assessment as one of the fundamental steps to be considered in analysing new teaching processes guided by AI (Miao and Yao, 2021; Faustino and Kaur, 2022; Lameras, 2022; Lameras and Arnab, 2022; Liu Y. et al., 2022). The level of attention on evaluation is probably due to the close relation to one of the most focused aims of AI applications, namely the personalization of students' learning pathways (Li, 2020; Tapalova and Zhiyenbayeva, 2022). Indeed, personalization can only be thought of with a careful analysis of the student, as stated by Luckin et al. (2016), who identifies the definition of the student model as one of the main issues.

The irruption of AI in assessment processes increases the possibilities regarding the object (what), time (when), and context (where) of evaluation.

Concerning the "what" point, in addition to the level of assessment of knowledge and skills gained by students in particular domains, it is stimulating that some authors focus on analysing students' behaviors and assessing their psychological state. Specifically to the latter point, considering the student's emotional state as an element to be evaluated to facilitate effective learning plays a primary role. According to Huang et al. (2021), AI thus enhances the assessment process by giving more significant importance than before to the assessment of learning processes and individual student development (Lau et al., 2014). A perspective that delineates the potential shift from unidirectional toward bidirectional evaluation (Huang et al., 2021; Hao, 2022).

Liu M. et al. (2022) highlight how the introduction of AI allows teachers to provide prompter evaluation reducing the time delay between the learning process and the feedback to the student ("when"). Consequently, AI potentially enhances the teaching process making the evaluation more pertinent in terms of learning effectiveness and the ability to adapt to students' subjectivity. In other words, AI tools for evaluation enable a shift from summative assessment to adaptive assessment necessary for formative feedback (Lameras, 2022).

Concerning the "where" point, online systems like MOOC or Intelligent-Tutoring Systems represent a natural context in which AI-based evaluation tools could show their potential (Chassignol et al., 2018; Shuguang et al., 2020). Nevertheless, some authors dwell on specific case studies such as assessing students' behavior during a lecture or monitoring students through a video camera as they take, for example, proctored exams (Edwards, 2021; Johri, 2022). As highlighted in the Section 3.1, AI contributes to a shift toward an enhanced school environment outlined by some authors with the terms smart or future classroom (Zhang, 2014; Kowch and Liu, 2018; Zhang Y. et al., 2021; Dimitriadou and Lanitis, 2022; Liu M. et al., 2022).

Of course, introducing video-based monitoring (VbM) for exams and assignments in a classroom environment raises the ethical issue disruptively. Nevertheless, the ethical issue relates to different aspects of the evaluation process, from automatic grading to predictive analysis. As reported by Johri (2022), there are already "systems in use now that help to predict student success based on their prior performance" (Shuguang et al., 2020). In fact, the introduction of AI in assessment processes also opens up new scenarios for analysing prediction scenarios made possible by specific techniques regarding significant aspects such as students' drop-out.

The literature analysis also reveals that connected to the theme of assessment is the theme of teacher support systems for evaluating phenomena such as copying and cheating, often resulting from the use of AI systems themselves, as in the case of translation tools (He, 2021). This issue naturally also reverberates to updating teaching strategies described in the Section 3.2.

Regarding disciplines, case studies related to English Teaching (ET) (Hou, 2020; Li, 2020; Zheng and Zhu, 2021; Liu and Huang, 2022), engineering (Megahed et al., 2022), music (Dai, 2021), anatomy (Abdellatif et al., 2022) and movement monitoring in the field of physical education (Cao et al., 2022) stand out among the selected articles. According to Li (2020), the capability of AI technology to accurately distinguish students' grammar mistakes and the opportunity to strengthen students' abilities to converse thanks to speech recognition features confirm the role of AI as an excellent auxiliary to the work of teachers in ET.

Regarding the school level, most articles introduce the topic of assessment. Nevertheless, of particular interest is the article proposed by Su and Yang (2022), in which a scoping review on the

use of AI in early childhood education is presented. In this review, some papers focus on student assessment and the changes produced by the introduction of AI.

Finally, many of these articles dwell on analysing specific AI techniques, among which emerge neural networks, with particular reference to convolutional networks (CNNs) and Bayesian models, both in classical and deep versions. A cross-cutting aspect of all these papers is the focus on teacher training in this area.

3.5. Teachers' professional development

The picture that emerges from the literature clearly shows how the figure of the teacher today is not sufficiently trained and equipped to deal with the new role that the AI era imposes on them. The most common problem that emerges from the analysis of the papers is precisely the low level (and in some cases the absence) of adequate digital skills (Hou, 2020; Edwards, 2021; Wang C, 2021; Ahmed et al., 2022; Bucea-Manea-oniş et al., 2022; Cao and Li, 2022; Kim and Kim, 2022; Yang, 2022; Dimitriadou and Lanitis, 2023). Whether it stems from the age of the teaching class, or from the habit of using more traditional media and methodologies, today's teachers are not up-to-date with the latest technologies (especially AI-based ones) and rarely have adequate knowledge of the tools available within their subject area. Moreover, in order to cope with the evolution of the educational paradigm introduced by AI, it is necessary for teachers not only to be trained in the use of technologies, with a particular focus on the tools used within their discipline (such as automatic translators in the context of second-language teaching), but also to be instructed in their underlying functioning mechanisms. The mere knowledge of these technologies and tools is in fact less important than the ways in which they are configured, situated and used in teaching practice (Johri, 2022). These tools need to be efficiently integrated within teaching activities, exploiting and assisting the new emerging methodologies and embracing their opportunities within the pedagogical dimension (Liu and Wang, 2020; Nye et al., 2021).

Similarly, just as it is important to train teachers on AI, new technologies, and the mechanisms by which these work, it is also important to structure training courses that will last over time and prevent the educational structure from taking a mere isolated step forward. What is needed is precisely to plan a path whereby continuous training becomes a habit through which teachers can keep up and be ready to interface with an ever-changing market and world in which new generations of students are born, grow and develop natively (He, 2021; Jiang, 2021; Hao, 2022). This problem must be addressed in a systemic manner and cannot be left solely to the teachers. In fact, one of the main reasons why new technologies arrive late in the school context is precisely the tendency to use and introduce only mature technologies (He, 2021), which have been thoroughly proven over the years, but which run the risk of becoming obsolete in a world evolving at the impressive speed at which innovation in AI is traveling.

An interesting result is to be found in the works of Bucea-Manea-oniş et al. (2022) and Kim and Kim (2022): in contrast to the prejudice that sees teachers as opposed to the introduction and use of AI within their own activities, these studies show that in reality educators, especially after direct exposure to the world of artificial intelligence, welcome the change. In fact, the greatest point of fear or insecurity often does not lie in the technology itself, but rather in the ethical and privacy issues surrounding its use within the pedagogical framework (Bucea-Manea-oniş et al., 2022). This suggests that there is within the teaching staff a certain awareness of what was discussed earlier, namely the need to evaluate and learn to integrate these technologies not as mere materials but as pedagogical tools.

For these reasons, and for what has been discussed in Section 3.2, it is important that the training of today's and tomorrow's teachers is systemic and structured to ensure continuous training over time, not limited to the technological part, but complemented by methodological training and the development of emotional, ethical and empathy skills (Miao and Yao, 2021), and that above all this training and these skills are approached holistically (Lameras and Arnab, 2022). Educators of the AI era must be able to be aware of the properties and opportunities offered by technology, they must be able to understand, collect, analyze and interpret the data provided by intelligent systems and integrate this within pedagogical methodologies (both new and old). They must be able to guide students within increasingly personalized educational pathways, and above all to change their role through the creation of ethical relationships with systems and digital assistants, in order to leverage the power of AI to better prepare students for lifelong learning.

4. Conclusions

The review study presented in this article is designed to provide a systematic picture of the critical dimensions related to the teacher figure in which AI plays and will be able to play a role as a catalyst for change. As detailed in the Section 2, starting from the analysis of previous studies that we considered relevant to the purpose of the review, we identified the following dimensions of analysis: teacher-student interaction, teaching methods and strategies, teaching content, students' assessment and monitoring, and teachers' professional development.

As seen in Section 3.1, the literature extensively describes and discusses the current state of the relationship between teachers and learners and the interactions that occur within it. Today, most of these interactions occur individually and in moments that are severely limited both in terms of quantity and timing.

AI-Based tools such as Intelligent Tutoring Systems (ITS), chatbots, and robots are often seen as a threat and an attempt to replace the figure of the teacher, when in fact the literature shows us that they can be important tools through which to create new opportunities for interaction, improving the current state in both quantitative (more interactions) and qualitative (more efficient interactions) terms.

Further new opportunities are provided to us by the development of smart classrooms and new school environments that are highly integrated with technology and AI, forcing us to rethink the ways in which we teach and learn. In particular, one of the most disruptive features of AI is to provide agency to technology, transforming the human-machine relationship from

uni-directional to bi-directional. In the world of today and the future, machines independently and autonomously initiate interactions on a par with humans, and this new way of interacting requires profound ethical and methodological considerations. In light of all this, the teacher must revise their role, learning to coexist with AI and technology, seeing it as a collaborator rather than an antagonist, taking on the figure of an authoritative mentor and guide (especially in the ethical, emotional, and human perspective) and leaving behind that of the knowledge-holding authority.

The shift in the center of gravity of teaching processes and models from teacher-centered to learner-centered through AI frees the teacher from many of those activities that students used to perform and that required his or her direct help or supervision. The central concept of "personalized learning" makes it possible to develop and implement a systematic teaching model that accompanies the individual student's personalized learning pathways in space and time that goes beyond the classroom environment (pre-class, in-class, after-class). The analysis of the literature concerning the teaching methods and strategies has shown that a shift in the center of gravity of the educated process on the student is not, however, matched by a shift in scientific reflection on certain crucial dynamics deeply linked to teaching practices. It emerges that, due to the intervention of AI, teaching methodologies and strategies change, but, although the reflection relating to the wide range of possibilities that can be implemented thanks to AI technology has been expressed in depth, there seems to be a lack of an adequate and systematic reflection on the cognitive implications that these new methodologies entail or will entail. The figure of the teacher, in this context, is not relegated to the background, but the description of the new practices that can be implemented seems to confine it in limbo. Important issues such as the changes that occur in the thinking processes of both the student and the teacher (problem-solving processes, decision-making, critical thinking) as a direct effect of the action of these new methodologies are not examined in depth. The teachers' perception of the novelty is not adequately thematised. It is difficult to deduce from the papers what the skills required of the teacher should be to embrace such a change. And there is no in-depth and exhaustive thematisation of the new skills that the teacher, thanks to the new methods and strategies, will have to cultivate in the student.

Linked to teaching strategies is, of course, the issue of teaching content. The customization of teaching content made possible by AI technology implies that it needs to be, in contrast to the past, flexible, manipulatable, explorable, and automatically generated. This can enable teachers to deal with customisable teaching content that can increase students' sense of personal fulfillment and autonomy. However, this context reveals a clear tendency, perhaps even quite dated but still very risky, to conceive of a new role of the teacher in terms of a non-starring actor. The landscape that emerges about teaching content seems to be built on two main focuses: (1) the student and (2) the AI technology that enables the personalization of resources. Between these two cores would move the teacher who, thanks to the technology he or she has at his or her disposal, can analyze student data to implement the personalization process or, possibly, select, according to teaching objectives, the resources to be included in the courses. There are almost no references to the crucial phases, didactic implications and problems of the customization processes of resources, and what role the teacher can play in them. There is a lack of in-depth focus on the centrality of the teacher in giving methodological direction to the process of constructing teaching content (from design to delivery) and on the skills that the teacher must acquire in the management of AI technology both in the phases of the teaching content generation process and in the delivery phases.

The literature review shows that evaluation is one of the most debated topics when considering the application of AI in educational processes. Firstly, assessment has intrinsic value as it is considered a crucial step in teaching methods. Furthermore, AI-based assessment exploits models and techniques in which AI has proven to be particularly effective, such as modeling and classification tasks. The analysis reported in Section 3.4, suggests that AI and learning analytics can help teachers in various activities and positively influence teaching processes. Furthermore, the evaluation also plays an essential role in other processes related to the application of AI in education, such as the personalization of student learning paths. AI integration in assessment processes could enhance it by extending the what, when, and where (in what context) to evaluate the student. Several studies suggest how AI can support the teacher during the assessment process by fostering a greater focus on learning processes and individual student development and enabling faster assessments and formative feedback.

With regard to the professional level and competency framework of teachers, as discussed in Section 3.5, the literature clearly emphasizes that substantial change is needed in order to cope with the evolutionary wave that the AI era brings. The teacher of tomorrow needs careful training that will enable them not only to acquire the necessary digital competences and skills but, even more importantly, to deeply understand the underlying mechanisms of how these new technologies work, so as to be able to integrate and situate them within the didactic pathways in a way that serves pedagogical purposes. It is necessary for teacher training to move from the sphere of pure knowledge of the relevant subject to that of the higher-level cognitive processes that affect learning, so as to be able to make the necessary change of role and truly prepare students for a personalized lifelong learning path. The teacher of the AI era must be a charismatic, empathetic educator able to build ethical relationships and interactions with the intelligences and digital tools that will assist them in their work. Moreover, it is important that this training embraces all these elements in a holistic manner, and above all that it is systematized at an organizational level so as to create continuous training paths that keep teachers up-to-date and ready to face tomorrow's developments.

The picture offered by the systematic analysis of the literature conducted in this study reveals a less than total awareness of the urgency with which the challenges imposed by AI in the educational field must be addressed. For this reason, we propose a kind of manifesto (see Figure 5) for guiding the change of the teacher's role that can reaffirm a "new centrality" of the role, forcefully countering the idea that it can be relegated to a mere mediator or tutor of a path built by "an artificial intelligence." As described by Johri (2022), this urgency originates from the enormous difference introduced by AI compared to other technologies from the point of view of agency. The autonomy that characterizes such technologies, their ability to be initiators of interaction with students, and the complexity of the

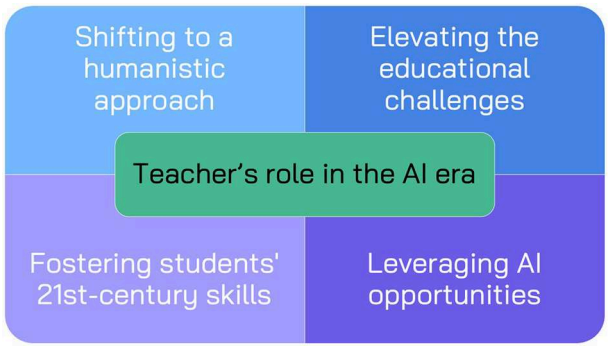

FIGURE 5
A manifesto for the new teacher's role in the AI era.

tasks that AI can already perform and increasingly will be able to do, imposes an evolution of the teacher's role. An evolution that can preserve, or perhaps restore, that beneficial authoritativeness that makes the teacher the point of reference in the student's growth path.

Such a manifesto must, in our opinion, start from a few main points:

- Shifting the teaching objectives from a disciplinary to a "humanistic" approach by focusing on the individual as a person and as a social group member. The teacher should play a more significant role in shaping people, their brains, souls, and moral values than before.
- Elevating the level of the challenges posed to our students. In the AI era, the teacher can no longer ask students the same outcomes that they are used to asking in the past. We need to demand a quantum leap toward students able to actively learn, discover problems, communicate and interact, and deal with complex problems.
- Fostering the development of students' twenty-first-century skills. Teachers should focus toward social skills like collaboration, autonomy and exploration as well as the high-level cognitive processes that characterize them (e.g., critical thinking, problem-solving, etc.).
- Leveraging the opportunities AI provides for designing and implementing innovative teaching methods, managing workload, and extending and enhancing the educational space-time continuum.

Fostering this paradigm shift cannot work only through groundwork on the technological skills of the teacher. Promoting the teachers' awareness about the points listed in our manifesto is a must to do action for all the national educational systems. Teachers should be conscious of the need to become the principal actor of a continuous innovation process from methodological, psychological and cognitive points of view.

We like to conclude this paper with a paraphrase of Kuhn's statement about the paradigm shift in science. To do so, we have taken the liberty of substituting the term "scientist" with the term "teacher" and the term "research" with the term "teaching" in an excerpt from the tenth chapter of the book "The Structure of Scientific Revolutions" (Kuhn, 1962), which is entitled "Revolutions as Changes in Worldview."

The portion of the following text is a perfect synopsis of what we have attempted to depict in this paper.

> *Nevertheless, paradigm changes do cause* ***teachers*** *[scientists] to see the world of their* ***teaching*** *[research] differently. In so far as their only recourse to that world is through what they see and do, we may want to say that after a revolution* ***teachers*** *[scientists] are responding to a different world. [...] Therefore, at times of revolution, when the* ***traditional educational methods*** *[normal-scientific tradition] changes,* ***teachers'*** *[scientists'] perception of his environment must be re-educated - in some familiar situations he must learn to see a new gestalt. [It happens that at the beginning of this process of change, the teacher has to] puts on goggles fitted with inverting lenses and initially sees the entire world upside down. At the start, his perceptual apparatus functions as it had been trained to function in absence of the goggles, and the result is extreme disorientation, an acute personal crisis. But after the [teacher] has begun to learn to deal with his new world, his entire visual field flips over, usually after an intervening period in which vision is simply confused. [...] Literally, as well as metaphorically, the man accustomed to inverting lenses has undergone a revolutionary transformation of vision.*

Author contributions

MG: conceptualization, data curation, formal analysis, methodology, supervision, visualization, writing—original draft, writing—review, and editing. GC and SP: conceptualization, data curation, formal analysis, methodology, visualization, writing—original draft, writing—review, and editing. MA: conceptualization, methodology, supervision, visualization, writing—review, and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Abdellatif, H., Al Mushaiqri, M., Albalushi, H., Al-Zaabi, A. A., Roychoudhury, S., and Das, S. (2022). Teaching, learning and assessing anatomy with artificial intelligence: the road to a better future. *Int. J. Environ. Res. Public Health* 19, 14209. doi: 10.3390/ijerph192114209

Ahmed, S., Khalil, M. I., Chowdhury, B., Haque, R., bin, S., Senathirajah, A. R., et al. (2022). Motivators and barriers of artificial intelligent (AI) based teaching. *Eurasian J. Educ. Res*. 100, 74–89. doi: 10.14689/ejer.2022.100.006

Alsheref, F. K., and Fattoh, I. E. (2020). "Medical text annotation tool based on IBM Watson platform," in *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)* (Coimbatore: IEEE), 1312–1316.

Asgari, H., and Antoniadis, G. (2021). "Mobile artefacts and language teaching, the example of the spoc+ platform," in *17th International Conferences Mobile Learning 2021 (ML 2021)* (Lisbonne).

Bucea-Manea-oni,ş, R., Kuleto, V., Gudei, S. C. D., Lianu, C., Lianu, C., Ili,ć, M. P., et al. (2022). Artificial intelligence potential in higher education institutions enhanced learning environment in romania and serbia. *Sustainability* 14, 5842. doi: 10.3390/su14105842

Caijun, W., Xi, J., and Zhenzhou, Z. (2021). "Analysis of systematic reform of future teaching in the age of artificial intelligence," in *2021 2nd International Conference on Artificial Intelligence and Education (ICAIE)* (Dali), 704–707. doi: 10.1109/ICAIE53562.2021.00154

Cao, F., Xiang, M., Chen, K., and Lei, M. (2022). Intelligent physical education teaching tracking system based on multimedia data analysis and artificial intelligence. *Mobile Inf. Syst*. 2022, 1–11. doi: 10.1155/2022/7666615

Cao, H., and Li, H. (2022). "Research and innovation of interior design teaching method based on artificial intelligence technology "promoting teaching with competition,"" in *Frontier Computing*, eds J. C. Hung, N. Y. Yen, and J.-W. Chang (Singapore: Springer Nature Singapore), 780–789.

Chassignol, M., Khoroshavin, A., Klimova, A., and Bilyatdinova, A. (2018). Artificial intelligence trends in education: a narrative overview. *Procedia Comput. Sci*. 136, 16–24. doi: 10.1016/j.procs.2018.08.233

Conklin, T. A. (2016). *Knewton An Adaptive Learning Platform*. Available online at: https://www.knewton.com/

Cumming, G. (1998). Artificial intelligence in education: an exploration. *J. Comput. Assist. Learn*. 14, 251–259. doi: 10.1046/j.1365-2729.1998.1440251.x

Cumming, G., Sussex, R., Cropp, S., and McDougall, A. (1997). "Learner modelling: lessons from expert human teachers," in *Artificial Intelligence in Education: Knowledge and Media in Learning Systems, Volume 39 of Frontiers in Artificial Intelligence and Applications, 8th World Conference on Artificial Intelligence in Education - Knowledge and Media in Learning Systems (AI-ED 97)*, eds B. duBoulay and R. Mizoguchi (Kobe), 577–579.

Dai, D. D. (2021). Artificial intelligence technology assisted music teaching design. *Sci. Program*. 2021, 1–10. doi: 10.1155/2021/9141339

Dieterle, E., Dede, C., and Walker, M. (2022). The cyclical ethical effects of using artificial intelligence in education. *AI Soc*. 2022, 1–11. doi: 10.1007/s00146-022-01497-w

Dimitriadou, E., and Lanitis, A. (2022). "The role of artificial intelligence in smart classes: a survey," in *2022 IEEE 21st Mediterranean Electrotechnical Conference (MELECON)* (Palermo: IEEE), 642–647.

Dimitriadou, E., and Lanitis, A. (2023). A critical evaluation, challenges, and future perspectives of using artificial intelligence and emerging technologies in smart classrooms. *Smart Learn. Environ*. 10, 12. doi: 10.1186/s40561-023-00231-3

Edwards, B. I. (2021). *Emerging Trends in Education: Envisioning Future Learning Spaces and Classroom Interaction*. Singapore: Springer Singapore.

Faustino, A., and Kaur, I. (2022). Artificial intelligence and machine learning: future of education. *AIP Conf. Proc*. 2555, 050031. doi: 10.1063/5.0109332

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., et al. (2018). AI4people— ethical framework for a good AI society: opportunities, risks, principles, and recommendations. *Minds Mach*. 28, 689–707. doi: 10.1007/s11023-018-9482-5

Gomez, F. J., and Schmidhuber, J. (2005). "Co-evolving recurrent neurons learn deep memory pomdps," in *Proceedings of the 7th Annual Conference on Genetic and Evolutionary Computation, GECCO '05* (New York, NY: Association for Computing Machinery), 491–498.

Hao, X. (2022). Innovation in teaching method using visual communication under the background of big data and artificial intelligence. *Mobile Inf. Syst*. 2022, 1–9. doi: 10.1155/2022/7315880

He, Y. (2021). Challenges and countermeasures of translation teaching in the era of artificial intelligence. *J. Phys. Conf. Ser*. 1881, 022086. doi: 10.1088/1742-6596/1881/2/022086

Hodgson, D., Goldingay, S., Boddy, J., Nipperess, S., and Watts, L. (2021). Problematising artificial intelligence in social work education: challenges, issues and possibilities. *Br. J. Soc. Work* 52, 1878–1895. doi: 10.1093/bjsw/bcab168

Holmes, W., Bialik, M., and Fadel, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*, Boston, MA: Center for Curriculum Redesign.

Holmes, W., and Porayska-Pomsta, K. (2023). *The Ethics of Artificial Intelligence in Education: Practices, Challenges, and Debates*. New York, NY: Routledge; Taylor & Francis Group.

Holmes, W., and Tuomi, I. (2022). State of the art and practice in scpAI/scp in education. *Eur. J. Educ*. 57, 542–570. doi: 10.1111/ejed.12533

Holmes, W., Persson, J., Chounta, I.-A., Wasson, B., and Dimitrova, V. (2022). *Artificial Intelligence and Education: A Critical View Through the Lens of Human rights, Democracy and the Rule of Law*. Council of Europe.

Hou, Y. (2020). "Foreign language education in the era of artificial intelligence," in *Big Data Analytics for Cyber-Physical System in Smart City*, eds M. Atiquzzaman, N. Yen and Z. Xu (Singapore: Springer Singapore), 937–944.

Huang, J., Shen, G., and Ren, X. (2021). Connotation analysis and paradigm shift of teaching design under artificial intelligence technology. *Int. J. Emerg. Technol. Learn*. 16, 73–86. doi: 10.3991/ijet.v16i05.20287

Huang, L., and Gupta, P. (2022). An empirical study of integrating information technology in english teaching in artificial intelligence era. *Sci. Program*. 2022, 5097. doi: 10.1155/2022/6775097

JabRef Development Team (2021). *Jabref – An Open-Source, Cross-Platform Citation and Reference Management Software, Version 5.1*. Available online at: https://www.jabref.org

Jiang, Z. (2021). "Discussion on artificial intelligence and information technology application of in the teaching of ideological and political courses," in *2021 4th International Conference on Information Systems and Computer Aided Education, ICISCAE 2021* (New York, NY: Association for Computing Machinery), 881–884. doi: 10.1145/3482632.3483042

Johri, A. (2022). Augmented sociomateriality: implications of artificial intelligence for the field of learning technology. *Res. Learn. Technol*. 30, 2642. doi: 10.25304/rlt.v30.2642

Kay, J. (2012). AI and education: grand challenges. *IEEE Intell. Syst*. 27, 66–69. doi: 10.1109/MIS.2012.92

Khan, A., Hasana, M. K., Ghazal, T. M., Islam, S., Alzoubi, H. M., Mokhtar, U. A., et al. (2022). "Collaborative learning assessment *via* information and communication technology," in *2022 RIVF International Conference on Computing and Communication Technologies (RIVF)* (Ho Chi Minh City: IEEE).

Khusyainov, T. M. (2022). *Uberization of Education: Critical Analysis*. Cham: Springer International Publishing.

Kim, N. J., and Kim, M. K. (2022). Teacher's perceptions of using an artificial intelligence-based educational tool for scientific writing. *Front. Educ*. 7, 755914. doi: 10.3389/feduc.2022.755914

Kowch, E. G., and Liu, J. C. (2018). "Principles for teaching, leading, and participatory learning with a new participant: AI," in *2018 International Joint Conference on Information, Media and Engineering (ICIME)* (Osaka), 320–325. doi: 10.1109/ICIME.2018.00075

Kuhn, T. (1962). *The Structure of Scientific Revolutions. International Encyclopedia of Unified Science: Foundations of the unity of Science v. 2*, Chicago: University of Chicago Press.

Kuka, L., Hörmann C., and Sabitzer, B. (2022). *Teaching and Learning with AI in Higher Education: A Scoping Review*. Cham: Springer International Publishing.

Lameras, P. (2022). "A vision of teaching and learning with AI," in *2022 IEEE Global Engineering Education Conference (EDUCON)* (Tunis: IEEE), 1796–1803.

Lameras, P., and Arnab, S. (2022). Power to the teachers: an exploratory review on artificial intelligence in education. *Information* 13, 14. doi: 10.3390/Info13010014

Latour, B. (2007). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Lau, T. P., Wang, S., Man, Y., Yuen, C. F., and King, I. (2014). "Language technologies for enhancement of teaching and learning in writing," in *Proceedings of the 23rd International Conference on World Wide Web* (ACM).

Li, J. (2021). "Research on intimacy between teachers and students in english classrooms in the context of artificial intelligence," in *2021 International Conference on Forthcoming Networks and Sustainability in AIoT Era* (Nicosia: FoNeS-AIoT), 43–46. doi: 10.1109/FoNeS-AIoT54873.2021.00019

Li, Y. (2020). "Application of artificial intelligence in higher vocational english teaching in the information environment," in *Innovative Computing*, eds C.-T. Yang, Y. Pei, and J.-W. Chang (Singapore: Springer Singapore), 1169–1173.

Litman, D. (2016). Natural language processing for enhancing teaching and learning. *Proc. AAAI Conf. Artif. Intell.* 30, 9879. doi: 10.1609/aaai.v30i1.9879

Liu, J., and Wang, S. (2020). "The change of teachers role in teaching under the environment of "artificial intelligence +."" in *2020 International Conference on Artificial Intelligence and Education (ICAIE)* (Tianjin, China), 98–102. doi: 10.1109/ICAIE50891.2020.00030

Liu, M., Zhou, R., Dai, J., Feng, X., and Tang, Y. (2022). Analysis and practice of using modern information technology for classroom teaching mode reform. *Mob. Inf. Syst.* 2022, 2565735. doi: 10.1155/2022/2565735

Liu, X., and Huang, X. (2022). Design of artificial intelligence-based english network teaching (AI-ENT) system. *Math. Probl. Eng.* 2022, 1–12. doi: 10.1155/2022/1849430

Liu, Y., Chen, L., and Yao, Z. (2022). The application of artificial intelligence assistant to deep learning in teachers' teaching and students' learning processes. *Front. Psychol.* 13, 929175. doi: 10.3389/fpsyg.2022.929175

Luckin, R., Holmes, W., Griffiths, M., and Forcier, L. B. (2016). *Intelligence unleashed: An argument for ai in education*. Technical report, London.

Megahed, N. A., Abdel-Kader, R. F., and Soliman, H. Y. (2022). "Post-pandemic education strategy: framework for artificial intelligence-empowered education in engineering (aied-eng) for lifelong learning," in *The 8th International Conference on Advanced Machine Learning and Technologies and Applications (AMLTA2022)*, eds A. E. Hassanien, R. Y. Rizk, V. Snášel, and R. F. Abdel-Kader (Cham: Springer International Publishing), 544–556.

Miao, F., Holmes, W., Huang, R., Zhang, H., et al. (2021). *AI and Education: A Guidance for Policymakers*. UNESCO Publishing.

Miao, Y., and Yao, Y. (2021). "Professional development of college teachers in the era of artificial intelligence: role rebuilding and development path," in *Application of Intelligent Systems in Multi-modal Information Analytics*, eds V. Sugumaran, Z. Xu, and H. Zhou (Cham: Springer International Publishing), 618–626. doi: 10.1007/978-3-030-51431-0_89

Moreno-Guerrero, A.-J., López-Belmonte, J., Marín-Marín, J.-A., and Soler-Costa, R. (2020). Scientific development of educational artificial intelligence in web of science. *Future Internet* 12, 124. doi: 10.3390/fi12080124

Niu, L. (2022). Analysis of multimodal teaching of college english under the background of artificial intelligence. *Security Commun. Netw.* 2022, 3833106. doi: 10.1155/2022/3833106

Nye, B. D., Shiel, A., Olmez, I. B., Mittal, A., Latta, J., Auerbach, D., et al. (2021). Virtual agents for real teachers: applying AI to support professional development of proportional reasoning. *Int. Flairs Conf. Proc.* 34, 128574. doi: 10.32473/flairs.v34i1.128574

Open,AI. (2021). *Gpt-3: The third-generation generative pretrained transformer language model*. Technical report.

Orlikowski, W. J. (2008). "Using technology and constituting structures: a practice lens for studying technology in organizations," in *Resources, Co-Evolution and Artifacts. Computer Supported Cooperative Work* (London: Springer). doi: 10.1007/978-1-84628-901-9_10

Orlikowski, W. J. (2002). Special issue: Knowledge, knowing, and organizations: knowing in practice: enacting a collective capability in distributed organizing. *Organ. Sci.* 13, 249–273. doi: 10.1287/orsc.13.3.249.2776

Orlikowski, W. J., and Scott, S. V. (2008). 10 sociomateriality: challenging the separation of technology, work and organization. *Acad. Manag. Ann.* 2, 433–474. doi: 10.5465/19416520802211644

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ* 372, n160. doi: 10.1136/bmj.n160

Pedro, F., Subosa, M., Rivas, A., and Valverde, P. (2019). *Artificial intelligence in education: Challenges and opportunities for sustainable development*. Technical report.

Ramesh, A., Pavlov, M., Goh, G., Gray, S., Voss, C., Radford, A., et al. (2021). Zero-shot text-to-image generation. *ArXiv*, abs/2102.12092. doi: 10.48550/arXiv.2102.12092

Rescigno, R. C. (1988). Practical implementation of educational technology. The GTE/GTEL smart-classroom. The hueneme school district experience. *Acad. Achiev.* 10, 1–27.

Salas-Pilco, S. Z., Xiao, K., and Hu, X. (2022). Artificial intelligence and learning analytics in teacher education: a systematic review. *Educ. Sci.* 12, 569. doi: 10.3390/educsci12080569

Sandanayake, T. C., and Bandara, A. M. (2019). Automated classroom lecture note generation using natural language processing and image processing techniques. *Int. J. Adv. Trends Comput. Sci. Eng.* 8, 1920–1926. doi: 10.30534/ijatcse/2019/16852019

Schroeder, K. T., Hubertz, M., Van Campenhout, R., and Johnson, B. G. (2022). Teaching and learning with ai-generated courseware: lessons from the classroom. *Online Learn.* 26, 73–87. doi: 10.24059/olj.v26i3.3370

Shuguang, L., Zheng, L., and Lin, B. (2020). "Impact of artificial intelligence 2.0 on teaching and learning," in *Proceedings of the 2020 9th International Conference on Educational and Information Technology, ICEIT 2020* (New York, NY: Association for Computing Machinery), 128–133.

Singer, U., Polyak, A., Hayes, T., Yin, X., An, J., Zhang, S., et al. (2022). Make-a-video: text-to-video generation without text-video data. *ArXiv*, abs/2209.14792. doi: 10.48550/arXiv.2209.14792

Sørensen, E. (2009). "The materiality of learning," in *Learning in Doing: Social, Cognitive and Computational Perspectives* (Cambridge: Cambridge University Press), 177–194.

Stone Wiske, M., Sick, M., and Wirsig, S. (2001). New technologies to support teaching for understanding. *Int. J. Educ. Res.* 35, 483–501. doi: 10.1016/S0883-0355(02)00005-8

Su, J., and Yang, W. (2022). Artificial intelligence in early childhood education: a scoping review. *Comput. Educ. Artif. Intell.* 3, 100049. doi: 10.1016/j.caeai.2022.100049

Suchman, L., and Suchman, L. A. (2007). *Human-Machine Reconfigurations: Plans and Situated Actions*. Cambridge University Press.

Tan, K.-H., and Lim, B. P. (2018). The artificial intelligence renaissance: deep learning and the road to human-level machine intelligence. *APSIPA Trans. Signal Inf. Process. 7*, E6. doi: 10.1017/ATSIP.2018.6

Tapalova, O., and Zhiyenbayeva, N. (2022). Artificial intelligence in education: aied for personalised learning pathways. *Electron. J. e-Learn.* 20, 639–653. doi: 10.34190/ejel.20.5.2597

Timofeeva, E. G., and Dorofeeva, A. A. (2022). Digital transformation of the russian historical education. *Galactica Media J. Media Stud.* 4, 284–294. doi: 10.46539/gmd.v4i4.350

Tuomi, I., Cabrera Giraldez, M., Vuorikari, R., and Punie, Y. (2018). "The impact of artificial intelligence on learning, teaching, and education," in *Anticipation and foresight KJ-NA-29442-EN-N (online)* (Luxembourg: KJ-NA-29442-EN-E).

Van Campenhout, R., Dittel, J. S., Jerome, B., and Johnson, B. G. (2021). "Transforming textbooks into learning by doing environments: An evaluation of textbook-based automatic question generation," in *Third Workshop on Intelligent Textbooks at the 22nd International Conference on Artificial Intelligence in Education* (CEUR Workshop Proceedings). Available online at: http://ceur-ws.org/Vol-2895/paper06.pdf

Vogt, P., van den Berghe, R., de Haas, M., Hoffman, L., Kanero, J., Mamus, E., et al. (2019). "Second language tutoring using social robots: a large-scale study," in *2019 14th ACM/IEEE International Conference on Human-Robot Interaction (HRI)* (Daegu: IEEE).

Wang, C. (2021). "The value orientation of teachers' role in artificial intelligence teaching environment based on information technology," in 2021 *4th International Conference on Information Systems and Computer Aided Education, ICISCAE 2021* (New York, NY: Association for Computing Machinery), 951–954.

Wang, D. (2021). "Changes and challenges: a study on the application of artificial intelligence technology in college english teaching," in *2021 4th International Conference on Information Systems and Computer Aided Education* (New York, NY: ACM), 1–6. doi: 10.1145/3482632.3483151

Yang, C. (2022). "The application of artificial intelligence in translation teaching," in *Proceedings of the 4th International Conference on Intelligent Science and Technology (ICIST)* (New York, NY: ACM), 1–7. doi: 10.1145/3568923.3568933

Ye, Z. Q. (2021). "Dual logic of teacher role transformation based on artificial intelligence," in *2021 2nd International Conference on Big Data and Informatization Education (ICBDIE)* (Hangzhou), 282–286. doi: 10.1109/ICBDIE52740.2021.00070

Yu, H., and Nazir, S. (2021). Role of 5g and artificial intelligence for research and transformation of english situational teaching in higher studies. *Mobile Inf. Syst.* 2021, 3414. doi: 10.1155/2021/3773414

Yusupova, S. B., Sultanov, O. R., Baltayev, R. S., and Bekchanov, F. A. (2022). "The advantage of using e-learning in teaching students programming languages," in *2022 IEEE International Multi-Conference on Engineering, Computer and Information Sciences (SIBIRCON)* (Yekaterinburg: IEEE).

Zhang, J. (2014). "Reconstructing new space for teaching and learning: the future classroom," in *Hybrid Learning. Theory and Practice*, eds S. K. S. Cheung, J. Fong, J. Zhang, R. Kwan, and L. F. Kwok (Cham: Springer International Publishing), 49–55.

Zhang, Y., Ning, Y., Li, B., and Liu, Y. (2021). "An innovative classroom teaching technology assisted by artificial intelligence of things," in *2021 2nd International Conference on Information Science and Education (ICISE-IE)* (Chongqing: IEEE), 1661–1664.

Zhang, Z., Hu, W., and Yang, Z. (2021). "Research on the innovation and development of visual communication design in the new media era," in *Advances in Social Science, Education and Humanities Research* (Paris: Atlantis Press).

Zheng, S., and Zhu, S. (2021). "A study of college english translation teaching in the age of artificial intelligence," in *2021 7th Annual International Conference on Network and Information Systems for Computers (ICNISC)*, 998–1000.

Zhou, Y. (2022). Research on innovative strategies of college students' english teaching under the background of artificial intelligence. *Appl. Math. Nonlinear Sci.* 2022, 272. doi: 10.2478/amns.2021.2.00272