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A Review of the Literature from 1970 to 2022 on the Roles of Teachers and Artificial Intelligence in the Field of AI in Education

Une recension des écrits de 1970 à 2022 sur les rôles de l'enseignant et de l'intelligence artificielle dans le domaine de l'IA en éducation

Una revisión de los escritos de 1970 a 2022 sobre los papeles del profesor y la inteligencia artificial en el campo de la IA en educación

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Alexandre Lepage, doctoral student in education
Université de Montréal, Canada
alexandre.lepage.2@umontreal.ca

Normand Roy, Professor
Université de Montréal, Canada
normand.roy@umontreal.ca

ABSTRACT

This article reviews the literature on the role of artificial intelligence (AI) and what teachershave envisioned in the field of artificial intelligence in education (AIED) since 1970. Forty-eight documents, most of them theoretical, were analyzed to identify what roles are given to AI in relation to learners, teachers, knowledge and the classroom as a whole (i.e. supporting motivation or providing personalized feedback). Quotes discussing teachers' role toward these components of learning situations were also analyzed (i.e. orchestrating interactions or evaluating learners). The results show considerable overlap between teachers' role and what AI is being developed to achieve in the field of AIED. Even if impossible in a predictable future,

the ambition of research in the field seems to be to automate a growing number of teachers' tasks. In the meantime, the role of teachers appears to be a dead angle in the field of AIED. The discussion proposes to reuse Faerber's ICT pyramid (2003), based on Houssaye's didactic triangle (1988/2015), to better study the role of AI in education in relation to those of teachers and learners.

Keywords: artificial intelligence, education, teacher, artificial intelligence in education, ICT

RÉSUMÉ

Cet article présente une recension des écrits sur la façon dont les rôles de l'enseignant et de l'intelligence artificielle (IA) sont abordés dans le domaine de l'intelligence artificielle en éducation (IAED) depuis 1970. Quarante-sept documents, théoriques pour la plupart, ont été analysés à partir des passages relatifs aux tâches confiées à une IA en lien avec les apprenants, les enseignants, les savoirs ou la classe (p. ex. le soutien à la motivation ou la rétroaction personnalisée). Les passages qui discutent du rôle de l'enseignant en lien avec ces différentes composantes ont aussi été analysés (p. ex. le pilotage des interactions en classe ou l'évaluation des apprenants). Les principaux résultats montrent que les développements dans le domaine de l'IAED couvrent un large spectre des attributions de l'enseignant et que, même si inatteignable sur un horizon prévisible, l'ambition scientifique du domaine semble être d'automatiser de plus en plus de tâches de l'enseignant. Il ressort que le rôle de l'enseignant est très peu discuté dans le domaine, et encore moins les interactions attendues entre enseignants et IA. La discussion propose de réemployer le tétraèdre des TIC en éducation de Faerber (2003), lui-même appuyé sur le triangle didactique de Houssaye (1988), pour conceptualiser le rôle de l'IA en éducation en interaction avec ceux de l'enseignant et de l'apprenant.

Mots-clés : intelligence artificielle, éducation, enseignant, intelligence artificielle en éducation, TIC

RESUMEN

Este estudio presenta una revisión de la literatura sobre cómo se han abordado los papeles del docente y de la inteligencia artificial (IA) en el campo de la inteligencia artificial en educación (AIED) desde 1970. Se han analizado cuarenta y ocho artículos, en su mayoría teóricos, a partir de los pasajes relacionados con las tareas encomendadas a una IA en relación con los alumnos, los profesores, el conocimiento o la clase (por ejemplo, apoyo a la motivación o retroalimentación personalizada). También se han analizado los pasajes que discuten el papel del profesor en relación con estos diferentes componentes (por ejemplo, la gestión de las interacciones en el aula o la evaluación de los alumnos). Los principales resultados muestran que los desarrollos en el campo de la IAED cubren un amplio espectro de atribuciones docentes y que, aunque inalcanzable en un horizonte previsible, la ambición científica en el ámbito parece ser automatizar cada vez más las funciones docentes. Parece que el papel del docente es muy poco discutido en el campo, y menos todavía las interacciones esperadas entre los docentes y la IA. La discusión propone reutilizar el tetraedro de las TIC en la educación de Faerber (2003), basado en el triángulo didáctico de Houssaye (1988/2015), para conceptualizar el papel de la IA en educación en interacción con el del docente y el del alumno.

Palabras clave: inteligencia artificial, educación, docente, inteligencia artificial en educación, TIC

Artificial intelligence in education (AIED) is a field of research whose beginnings can be traced back to the decade 1971-1980 (Self, 2016). Since then, a great deal of research has been carried out, leading to the development of a variety of digital tools including intelligent tutorial systems, conversational agents or, more recently, educational success dashboards. The field follows in the footsteps of computer-aided instruction and intelligent computer-aided instruction (Robertson, 1976) whose aim was to enable knowledge to be learned on a computer, with exercisers providing automatic feedback. According to Wenger (1986), unlike these two fields, the AIED field aimed to develop systems capable of making instructional decisions themselves, rather than applying pre-programmed decisions. In 1987, Romiszowski described the AIED field as one in which applications could serve either the teacher or the student, in one of three ways: as a tutor (computer-assisted learning), as a tool (use of expert systems) or as a learning object (learning to program a system). More recently, Lameras and Arnab (2021) reviewed the literature for the period 2008-2020 and identified that the AIED field could be broken down into five sub-fields: (1) content preparation and delivery, (2) helping students apply knowledge, (3) engaging students in tasks, (4) assessment and feedback, and (5) helping learners self-regulate.

Changes in the AIED field have been numerous since its inception, starting with the multiplication of data sources available to personalize learning according to individuals (Bull and Kay, 2016). This personalization, a central objective of research in the field (Dede *et al.*, 1985), is now based on a greater quantity of parameters determined by increasingly complex digital traces, and by predictive models established by massive data from a multitude of learners or use cases. The increasingly porous boundary between digital and physical spaces (Dillenbourg, 2016) also leads us to see the field of AIED as less and less hermetic, since the uses of AI in education can be studied via complex teaching-learning situations in the classroom, whether face-to-face or virtual, or via other disciplines such as assessment or instructional design. What's more, the techniques used to operate AIED systems have evolved. Romiszowski (1987) closely associated AIED with expert systems, which he defined as follows: "An expert system should help a novice, or partly experienced, problem-solver to match acknowledged experts in the particular domain of problem solving that the system is designed to assist" (p. 96). Today, the field of AIED is marked by the growing use of so-called connectionist AI (see Minsky, 1991), via machine learning, giving rise to new uses such as the prediction of academic success or the deployment of high-performance conversational agents.

The role of the teacher has received little attention in the field of AIED (du Boulay, 2021), with research focusing mainly on learner-knowledge interactions mediated by intelligent tutorial systems that can take the form of problem-solving assistants, mentors, laboratory assistants or expert consultants (Sleeman and Brown, 1982). Yet teachers are central to the process of pedagogical integration of digital technology, and any transfer of new technologies within the classroom starts with them. More and more systems aim to support interactions between teachers and learners (Timms, 2016), which calls for a definition of the teacher's role in relation to the use of AI. Like other digital technologies, the pedagogical integration of AI in education is only possible if it is first adopted by teachers. Secondly, it is through techno-pedagogical integration, now studied by specific frameworks such as the T-PACK model (Koehler and Mishra, 2009), that teachers will determine what is done before, during and after the use of a digital technology, with or without AI. He or she will also determine what is expected of the learner at each of these stages, and may combine several software applications to achieve a broader pedagogical objective than was intended when the technology was designed. The deployment of AIED systems in the classroom therefore necessarily involves teachers. But what is expected of them with regard to AI systems? What is their role? Does this software encroach on teachers' tasks? Are they better or worse than teachers at certain tasks? What new responsibilities do teachers have when using AI systems?

The relevance of this article lies mainly in the fear, founded or not, that AI could replace teachers. According to Renz and Vladova (2021), this fear of teacher replacement has slowed the progress of AI in education compared to other fields. For many, teachers are needed to manage particular situations that cannot be anticipated (Holmes *et al.*, 2021), make pedagogical decisions in the interests of the student and not the *Edtech* sector (Saltman, 2020) or simply to preserve human interactions (Renz and Vladova, 2021). For those people, the role of AI in education should rather be to support teachers in their actions (e.g., Bulger, 2016; Marrhich *et al.*, 2021). But the distinction between teacher replacement and teacher support is not so clear-cut in the case of a technology whose ambition is to reproduce a part of human intelligence. As Mubin *et al.* (2013) point out, the division of labour between educational robots and teachers needs to be clarified by going beyond the sterile dichotomy pertaining to replacement. The aim of the research is to analyze how the roles of teachers and AI have been described in the AIED field between 1970 and 2022. Achieving this objective will eventually help to identify areas of interaction between teachers and AI, as well as gaps that must be filled in terms of roles with learners.

Method

The method selected was that of a systematic review based on the steps suggested by Rhoades (2011): identification of inclusion and exclusion criteria, scanning of titles and abstracts to exclude irrelevant studies, addition of references deemed missing, detailed analysis of relevant studies, data extraction, synthesis and conclusion. An inductive analysis (Corbin and Strauss, 2015) was performed by establishing a code grid, stabilized after the first 10 papers, with MaxQDA software. Title and abstract scanning was carried out by one of the authors, as was document coding. The code grid was adjusted and validated by both authors.

Databases consulted

The following databases were searched on November 1st 2022: Web of Science (71 results), ACM Digital Library (6), Science Direct (8), Erudit (3), Academic Search Premier and Education Source (39), Taylor and Francis (4), as well as 11 manual additions, which were deemed to be missing (e.g., via references to documents consulted or suggested during peer review). The search yielded no results in CAIRN or OpenEditions. The raw search yielded 142 results. After removing duplicates (n=17), applying exclusion criteria (Table 1, n=76), removing inaccessible documents (n=2), the final corpus comprises 47 documents (Figure **1**). Documents included in the corpus are marked with an asterisk in the reference list at the end.

Criteria for inclusion and exclusion of texts

As the review was specifically designed to identify publications in the field of AIED dealing with the role of teachers, the exact phrase “artificial intelligence in education” and the word “teacher*” were identified as the main inclusion criteria.

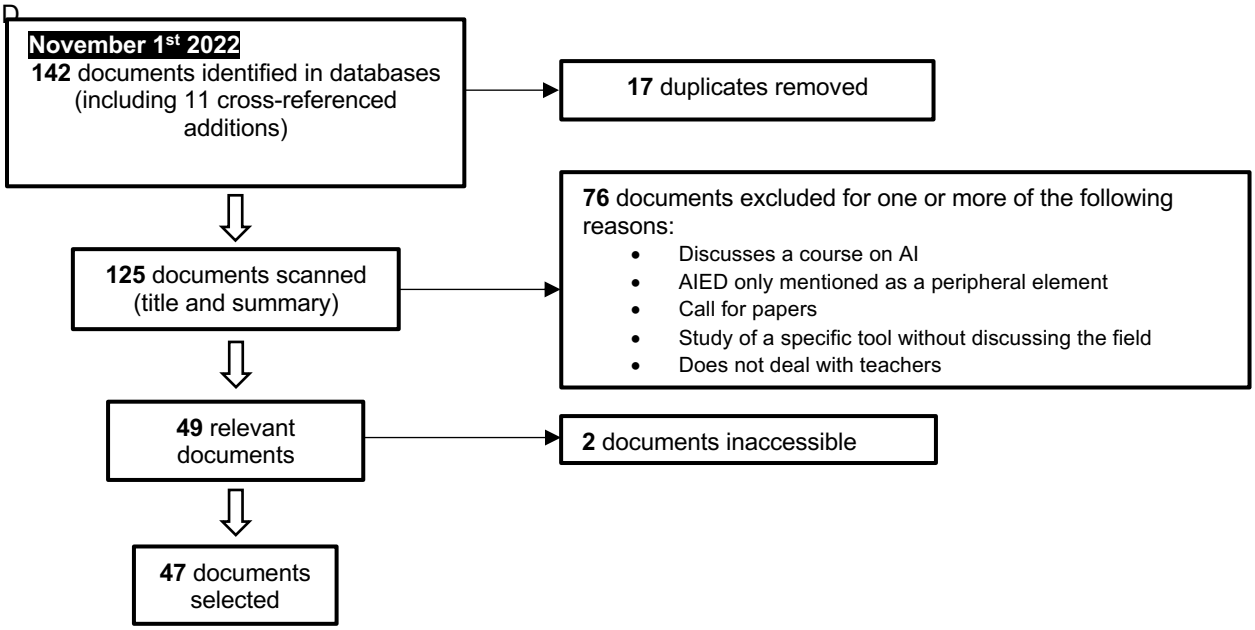
Table 1

Review inclusion and exclusion criteria

Search criteria	Values
Inclusion criteria	
Year of publication	1970 … 2022
Artificial intelligence in education	Title, abstract or keyword(s) contain(s): “artificial intelligence in education” **OR** “AIED” **OR** “intelligence artificielle en éducation”.
The teacher’s role	Title and abstract contain: teacher* **OR** enseignant*.
Exclude other definitions of the acronym AIED (*autoimmune inner ear disease*)	Title and abstract do not contain: “disease”.
Exclusion criteria (scanning of titles and abstracts)	
Article language	Not in English or French
Type of article	Editorials, data collection policies or calls for papers
Subject	Deals with medicine or health, deals with a specific tool without discussing the AIED field
Teachers	Does not address the teacher’s role in AIED

Figure 1

Corpus document selection process



Results

The aim of this section is to present the results in relation to the research objective, i.e., to present the way the roles of AI and teachers are approached in the field of AIED. The first section presents a description of the corpus, after which the roles of AI and teachers are discussed in turn. For each, results are separated according to interactions (e.g., role of AI or teacher with teachers, learners, knowledge and class). The final section presents specific results in relation to the explicit idea of teacher replacement.

Corpus description

A total of 65 coding categories were created and are presented in TTable 2 with the number of corresponding passages and the number of documents in which this category was used at least once. The role of AI in education was addressed at least once in 46 documents, and the role of teachers in 29 documents. The majority of documents are theoretical articles published in peer-reviewed journals (n=25).

Table 2

Coding grid with number of segments and number of documents per code

Code	Seg	Doc
Role of AI	**519**	**46**
Working with teachers	**106**	**26**
Provide teachers with information on learners	45	22
Modeling teachers' work	23	6
Helping with decision-making	19	12
Provide teachers with information on their practice	15	4
Facilitate collaboration and training among teachers	4	3
Role with learners	**273**	**43**
Provide accurate feedback	56	27
Modeling the learner	55	25
Personalizing learning	40	21
Supporting metacognition	38	18
Assessing learners	20	15
Supporting motivation	16	11
Detecting emotions	15	10
Building a relationship with the learner	12	3
Choosing teaching strategies	9	7
Guiding towards good learning strategies	7	6
Detecting plagiarism	3	2
Identifying at-risk students	2	2
Role in relation to knowledge	**105**	**31**
Modeling a knowledge domain	49	19
Choosing content and activities	20	14
Transmitting knowledge	18	14
Producing or enhancing digital educational resources	15	7
"Drill & practice" exercises	3	3
Role with the class	**34**	**11**
Supporting collaborative work	17	8
Classroom and behaviour management	8	1
Fueling discussion between teachers and learners	7	4
Modeling physical learning spaces	2	2

Code	Seg	Doc
The teacher's role	**132**	**29**
Role with the AI	**47**	**18**
Participating in the development of AI systems	22	10
Interpreting AI data	9	5
Entering data	8	7
Improving or correcting AI representations	5	3
Choosing AI tools	3	3
Role with learners	**36**	**17**
Supporting learner motivation	9	6
Representing and getting to know learners	8	7
Making accurate learning diagnoses	6	4
Providing feedback to learners	4	3
Assessing learners	3	3
Guiding towards good learning strategies	3	2
Selecting individual tasks	2	2
Supporting learners' metacognition	1	1
Role in relation to knowledge	**21**	**11**
Instructional planning	11	6
Creating digital educational resources	4	3
Determining elaborate teaching strategies	3	3
Transmitting knowledge	3	3
Role with the class	**28**	**14**
Interpreting a unique educational situation	8	3
Relating to the group	7	4
Managing exchanges and collaborative work	6	5
Creating and maintaining a healthy classroom climate	3	3
Performing non-goal-oriented peripheral actions	3	2
Negotiating with students	1	1
Teacher replacement	**143**	**38**
Transformation of the teacher's role	47	24
Benefits of AI for teachers	40	18
Teacher-AI-learner triangle	24	9
Advantages of the teacher over AI	22	13
Differences between an intelligent tutor and a teacher	10	7

Note: The number of segments coded at the 1st and 2nd levels is a subtotal. The passages have all been coded at the 3rd level. The number of documents at the 3rd level is the total number of documents with at least one coded passage. At the 1st and 2nd levels, this is the number of documents with at least one passage coded in one or more of the 3rd level codes.

Figures 2 to 4 show the distribution of documents by type, country of first author and year. The results are presented in order of the number of passages coded: role of AI (n=539) and role of the teachers (n=130).

Figure 2
Number of documents by country of first author

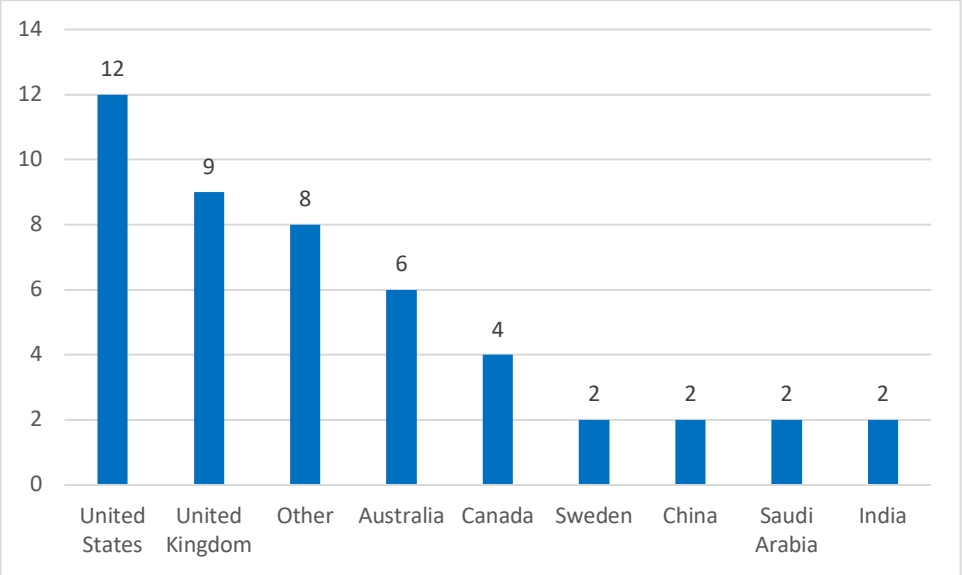


Figure 3
Number of documents by type of document

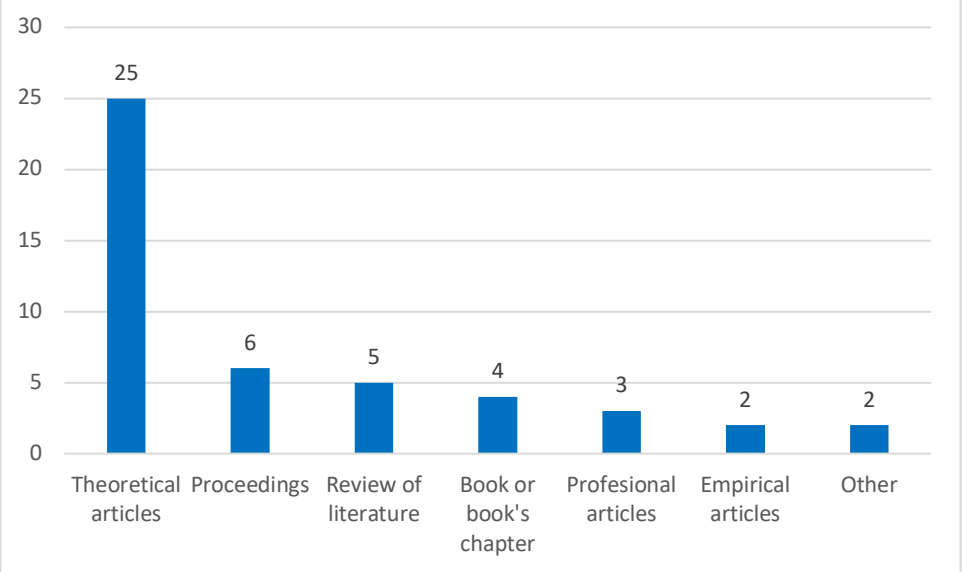
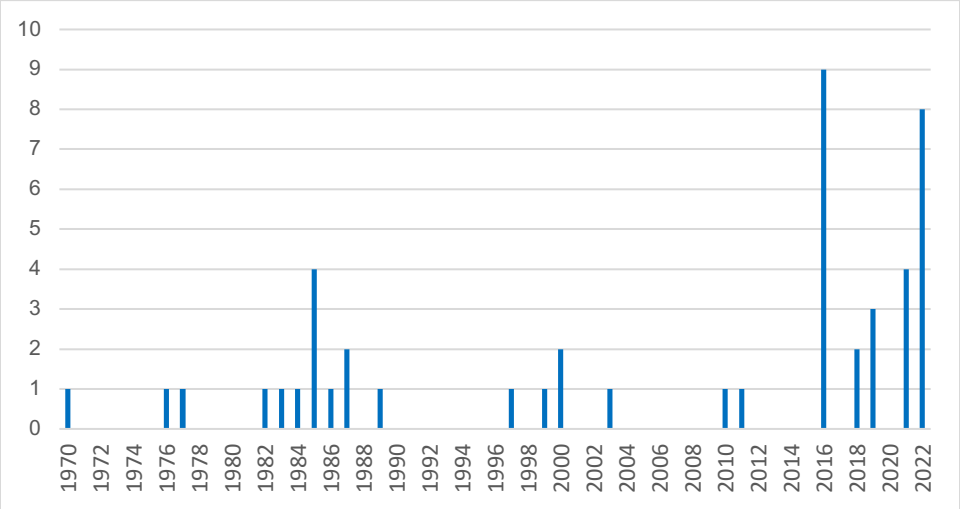


Figure 4
Number of documents by year of publication



The role of AI

AI'S ROLE WITH RESPECT TO TEACHERS

The main results relating to the role of AI concern decision support and the modeling of teachers' work.

First, AI can be used to help teachers make decisions. A dozen or so papers discuss decision support, but most do not go into more detail about the tasks that can be supported. These may include help with instructional design or the selection of educational resources (Celik *et al.*, 2022), help with diagnosing learning difficulties (Colbourn, 1985) or help with the whole range of everyday tasks. As such, Timms (2016) uses the concept of "educational cobot" (p. 703) to describe an intelligent assistant that would augment the teacher's capabilities. To support decision-making, AI systems may increase the information available to teachers. Colbourn (1985) proposes that AI systems can help teachers detect learning difficulties. More recently, several authors address the idea that AI makes it possible to collate data that would otherwise be impossible to obtain (Big data paradigm, Cox and Brna, 2016). In the field of learning analytics, dashboards for teachers make it possible to visualize cumulative information on the learning traces of learners individually or in groups (Lajoie, 2021). Success prediction tools are also used to provide teachers with additional information to support their decision-making (Dillenbourg, 2016; Yuskovych-Zhukovska *et al.*, 2022). According to Humble and Mozelius (2019), an intelligent tutorial system "needs not to be intelligent but rather designed intelligently to amplify the human tutor's already existing intelligence" (p. 5, drawing on Baker, 2016).

Second, AI is also being used to model the work of teachers, with the aim of reproducing their actions more faithfully. In this respect, recent articles show an intention to go beyond the simple modeling of a teacher's role as tutor, and also consider the relational aspect with learners. For example, Celik *et al.* (2022) report on studies in which attempts were made to analyze teachers' verbal communication or movements from video recordings to model their classroom behaviour. These uses can help to provide a better understanding of teachers' gestures so that they can be reproduced by an intelligent tutor, but for the moment they are mainly used to help future teachers develop a reflexive hindsight on their practice

(Porayska-Pomsta, 2016). In line with this idea of taking a reflective look at practice, du Boulay (2021) proposes that systems could be used to help teachers see the gaps between their classroom planning and the piloting experienced in the classroom.

AI'S ROLE WITH RESPECT TO LEARNERS

The main roles of AI with regard to learners that will be presented are, in order, modeling the learner, personalizing learning, providing feedback and building a relationship with the learner.

First, AIED systems comprise a learner model, a knowledge domain model and a teaching model (Crovello, 1985; Dede *et al.*, 1985). The learner model is used to store a representation of the learner's knowledge (Halff, 1986) and to update it as he or she learns with the system. The learner's model is then juxtaposed with the knowledge model or an expert's model, and is used to infer the learner's missing or erroneous knowledge (Brown, 1977; Burton and Brown, 1982). If the learner has integrated the knowledge correctly, he or she should produce the same responses as the knowledge model (Carbonell, 1970). Since the beginning of the AIED field in the 1980s, the possibilities for modeling the learner have increased tenfold, notably through the use of web-based tools that connect data from multiple learners to create more complex models (Bull and Kay, 2016). What's more, the proliferation of sensors for collecting data is leading to greater complexity in learner modeling by incorporating a wider variety (Dillenbourg, 2016). Learner models now tend to incorporate more and more data on students' emotional engagement and not just on their state of knowledge (du Boulay, 2021), as well as longitudinal data (Pinkwart, 2016). These models underpin any intervention that aims to personalize learning (Kay *et al.*, 2022). According to Lameras and Arnab (2021), the learner model should include six components: knowledge about the subject being learned, motivations to learn and expectations of the learning situation, prior experience of different learning modalities, preferences, social skills and confidence in using an adaptive learning system.

Second, based on the learner model, AIED systems aim to personalize the learning experience. This personalization can take place in a number of ways, for example by removing or adding options to software navigation (Brusilovsky and Peylo, 2003). It can also be achieved by adapting content to a person's interests (du Boulay, 2021; Khandelwal, 2021) or by gradually adjusting the level of difficulty. According to du Boulay and Luckin (2016), adaptation can be macro when it targets a group of people, or micro when it targets individuals.

Third, AIED systems aim to give rapid feedback to learners as mentioned by many authors (e.g., Dede *et al.*, 1985; Humble and Mozelius, 2019; Kann, 1983; Khan *et al.*, 2022; Stubbs and Piddock, 1985), sometimes in real time at the moment of performing a procedure. They can also consist of personalized cues, based on mistakes made by learners, to help them adjust their actions (Brown, 1977). Such feedback aims to regulate knowledge, support motivation to learn (e.g., Kim and Baylor, 2016; Walker and Ogan, 2016), encourage metacognitive reflection by interrupting the learner to suggest reflections (Dede *et al.*, 1985). Some systems aim instead for the learner to drive interactions with the system themselves by asking questions (Jonassen, 2011). Burton and Brown (1982) distinguish the tutor from the "coach" (p. 79), saying that the tutor acts more formally to supervise specific learning, while the coach is more focused on encouraging learning in an informal environment where the student has more initiative (e.g., a video game).

Finally, more recently, systems are placing value on building a relationship with the learner. Walker and Ogan (2016) propose to model these relationships between intelligent tutor and learner:

> We propose that AIED systems include designed relationships, or particular care be taken to construct the socio-motivational relationship between the AIED system and the student. As we

> note above, a growing body of literature suggests that socially-designed interactions with educational technologies can produce similar outcomes as social interactions amongst teachers and students or peer collaborators (p. 717).

More and more systems are aiming to detect emotions while performing a task. Various experiments are taking place, notably to assess the overall attention level of the class based on real-time video analysis (Raca *et al.*, 2014, cited in Dillenbourg, 2016), for facial recognition or eye tracking (Timms, 2016), or the classification of emotions (Lameras and Arnab, 2021).

In summary, the role of AI with respect to learners in the field of AIED has mainly been that of intelligent tutor for personalized learning and rapid feedback when solving a problem. The field is devoting more and more attention to relational and emotional aspects, and tends to extend the modeling of learners beyond cognitive aspects, which is made possible in particular by the multiplication of data sources.

THE ROLE OF AI IN RELATION TO KNOWLEDGE

The main roles of AI in relation to knowledge are knowledge modeling and knowledge transmission, which generally involves the production of learning resources.

First, knowledge modeling is mentioned in 19 of the 47 documents in the corpus, slightly less than learner modeling (25 documents). Knowledge modeling can be done by creating semantic networks (Halff, 1986) linking concepts together, or by extrapolating or inferring relationships from a knowledge base (e.g., Carbonell, 1970). It is on the basis of this modeling that AIED systems can make instructional decisions without having been explicitly programmed (Wenger, 1986).

Second, this knowledge modeling done or supported by the AI then enables the transmission of knowledge to learners. More specifically, the AI's role may be to select the knowledge to be transmitted (Brusilovsky and Peylo, 2003) or to demonstrate how to apply a technique (Stubbs and Piddock, 1985). Several papers mention knowledge transmission indirectly, for example, Ye *et al.,* (2021) referring to Skinner's learning machine or systems capable of answering content questions posed by learners (Jonassen, 2011; Stubbs and Piddock, 1985). Three articles, all from the 1980s, refer to a "Drill & practice" approach (Crovello, 1985; Kann, 1983; Stubbs and Piddock, 1985). AI systems can also be used to produce or enrich learning resources. This may involve producing material to meet a student's particular characteristics (du Boulay, 2021; Porayska-Pomsta, 2016), translating material or generating subtitles automatically (Khandelwal, 2021), or summarizing content (Malik *et al.*, 2019).

THE ROLE OF AI IN THE CLASSROOM

A number of recent documents assign roles to AI in classroom management. There are two such roles: supporting collaborative work or modeling learning spaces.

First, AI systems can be used to support collaboration among learners by structuring discussions to maximize their potential (Lameras and Arnab, 2021) or by calculating indicators of engagement in a collaborative project. For example, Lajoie (2021) reports the use of an online discussion system in which learners' contributions are analyzed and related to those of other learners. Dillenbourg (2016, building on Bachour *et al.*, 2010) reports the use of a table with indicator lights serving as indicators of speaking time used by individuals. AI can also power interactions between teacher and learners. Open learner models also fulfil this function, as they provide information about learning and learners (Kay *et al.*, 2022).

Second, in connection with the classroom, AI could increasingly be used to model physical learning spaces:

> […] while AIED initially aimed at modelling the contents and the learner, a challenge for the future of AIED is to model educational spaces, i.e., the physical space and the diverse actors who inhabit this space, in order to make education more effective. We conceptualized this evolution by defining a third circle of usability (Dillenbourg *et al.*, 2011), where the user is not an individual (first circle) or a team (second circle) but the entire classroom is viewed as a physical and sociological system. (Dillenbourg, 2016, p. 548)

Modeling the classroom means going beyond personalizing learning on a purely individual basis and integrating, as Dillenbourg points out, knowledge about the group and how it functions.

To sum up, the role of AI in the classroom is little discussed in the corpus. Nevertheless, it seems that the role of AI in the classroom is developing more in the AIED field today than in its early days (26 of the 34 passages coded in this category come from documents published after 2010), which is consistent with the growing interest in relational and affective aspects presented in the section on the role of AI in learners. This role may involve structuring exchanges or modeling both physical and digital learning spaces (Dillenbourg, 2016).

The teacher's role

THE TEACHER'S ROLE WITH RESPECT TO AI

The role of the teacher regarding AI is rarely mentioned in the corpus (47 passages in 18 documents). When it is, it is essentially in two respects: either as a passive user of the systems, or as an active user invited to configure a system or enter data.

As passive users of AIED systems, teachers may be required first and foremost to interpret information provided by AI: "teachers need to understand the results of intelligent analysis based on teaching situations and pedagogical theories, compare the gap between students' achievements, identify students learning needs, predict risks at academic failure, and even discovering new rules for AIED" (Liu and Li, 2022, p. 39). This role can be fulfilled to a greater or lesser extent depending on the teacher's level of data literacy (Howard *et al.*, 2022). As such, even passive use may involve teachers having to develop knowledge to integrate the use of AI into their teaching practice (Liu and Li, 2022; Pinkwart, 2016).

As active users, teachers may have to contribute to producing this data. Bull and Kay (2016) assert that the learner's model can either be controlled entirely by the system, or controlled jointly by the teacher and the system. Thus, in addition to interpreting data, the teacher could be required to enter or modify data to complexify or correct the learner model (Bull and Kay, 2016), including information relating to behaviours that would escape the digital traces (Celik *et al.*, 2022). According to Liu and Li (2022), teachers also have an ethical responsibility towards AI: "Teachers need to have the correct value judgment in deploying intelligent technology to promote students' learning and well-being, understand the potential risks of AIED, and handle the ethical issues in a prudent and responsible manner" (p. 37).

THE TEACHER'S ROLE WITH RESPECT TO LEARNERS

In the field of AIED, there is little discussion about the role of the teacher with respect to learners, and when it is, it often illustrates the gap between what AIED systems do and how much remains to be done to imitate or even replace the teacher. The teacher's main roles regading learners are to support motivation, accurately diagnose obstacles to comprehension and get to know the learners.

First, teachers are presented as essential players in supporting learner motivation. Liu and Li (2022) mention that the emotional work of teachers is essential to create a positive atmosphere that encourages the pleasure of learning and self-improvement. To create this atmosphere, Timms (2016) evokes the importance of teachers demonstrating a genuine and personal interest in learners beyond the subject matter.

Second, several authors have also mentioned the teacher's role in identifying learning pitfalls in complex situations or with fragmentary, disorganized and partial information (Les *et al.*, 1999), an idea also mentioned by (Carbonell, 1970): "Human teachers sometimes try to understand the nature of their students' confusions and problems, but at least as often, they go into explanatory and remedial sequences without a full understanding of the reasons for the students' errors." (pp. 198-199). Du Boulay (2021) stresses the importance of teachers in supporting metacognition to consolidate learning.

Finally, to fulfill these motivational support and pitfall identification roles, teachers need to know their learners and maintain mental representations of them (Goodyear *et al.*, 1989). This aspect has been referred to by several authors since the early days of the field, e.g., Crovello (1985) mentioning that teachers must have knowledge about each individual learner. Cumming *et al.* (1997) refer to cognitive, affective and social knowledge, some of which is dynamic and changes according to the situation, while others are long-term (e.g., learners' personality traits). Kay *et al.* (2022) speak of the "model of the learner in the mind of the teacher" and the "model of a set of learners" (p. 5).

In short, the teacher's role with respect to learners is essentially relational, and it is from this base that tasks related to learning support are carried out.

THE TEACHER'S ROLE IN RELATION TO KNOWLEDGE

The most discussed role of the teacher in relation to knowledge is instructional planning. Ahmad *et al.* (2022) speak of curriculum development or the creation of lesson plans, and Liu and Li (2022) even consider that "human teachers play irreplaceable roles in curriculum and creative professional practice compared with AI teachers" (p. 35). Teachers are required to create video resources and prepare lectures (Khandelwal, 2021) and develop resources using AIED tools (Yuskovych-Zhukovska *et al.*, 2022). Teachers are also responsible for transmitting knowledge and steering elaborate learning activities in real time, an aspect that until recently was neglected in the field of AIED according to Dillenbourg (2016): "The role of teacher during runtime did not receive much attention for two decades, but this changed a lot over the last decade, with the growing interest for the orchestration of computer-enhanced learning activities" (p. 555).

THE TEACHER'S ROLE IN RELATION TO THE CLASS

A few passages about learners described the teacher's work in relation to a group rather than individuals. The teacher enters into a relationship with a group by calling on communication skills that are not necessarily specific to teaching:

> While there are some specialized tactics that human teachers apply effectively, good teaching derives from the conversational and social interactive skills used in everyday settings such as listening, eliciting, intriguing, motivating, cajoling, explaining, arguing, persuading, enthralling, leading, pleading and so on. (du Boulay and Luckin, 2016, p. 396.)

In the same vein, Porayska-Pomsta (2016) refers to the need for "agile adaptation" (p. 685), also described as "teacher immediacy" by Walker and Ogan (2016, pp. 716-717), which includes spontaneous gestures such as smiling, eye contact, gesticulation or the use of common references.

Teacher replacement

Given that this literature review finds its relevance in fears, founded or unfounded, that AI could replace the teacher, we thought it useful to code the passages in the corpus that discussed precisely this idea.

References to the idea of replacement are generally very brief, for example Robertson, (1976) who states that "the idea is that such systems may make conventional teaching methods more effective, not that they should replace them" (p. 437). Conversely, Brusilovsky and Peylo (2003), referring to the field of computer-assisted instruction, assert that these systems "were intended to replace all or part of traditional classroom instruction" (p. 163). Colbourn (1985, p. 521) states that in some cases the system acts like a teacher, but in most cases it acts like a tutor to accompany learners in discovering information or laws for themselves. Dede *et al.* (1985) are more straightforward, speaking of the "potential for direct substitution of teacher activities" (p. 89) and wondering whether the future of the field will involve an intention to automate or accompany teacher activities. Kann (1983) argues that programs developed in AIED attempt to replicate the characteristics of the best teachers, such as engaging in two-way communication with learners and taking account of their interest in whether to pursue certain learning. More recently, Edwards and Cheok (2018) speak of AIED as a solution to the shortage of manpower in the field. Despite such formulations, which display the intention of replacing teachers in some of their activities, Dillenbourg (2016) asserts: "despite a few discordant voices ('neo-Illich' gurus), educational technology researchers have never believed that their technology would suppress the need for teachers in formal education" (p. 555). In his opinion, however, few studies have been carried out on the roles of teachers in systems developed in the field of AIED. Humble and Mozelius (2019) ask the question directly: is the aim of the AIED to support teachers or to replace them?

A number of authors point to the transformation of the role of teachers, as they become more involved in steering high-level activities (du Boulay, 2021). Time spent with students and their role may also change (du Boulay, 2021). They may also spend time participating in the co-design of AIED systems (Porayska-Pomsta, 2016). According to Yuskovych-Zhukovska *et al.* (2022):

> […] AI is consistently and confidently changing the role of teachers. AI can perform tasks such as assessment, can help learners improve learning, and can even replace real learning. AI systems can be a source of expertise to which students can direct their questions, or even take the teacher's place for the basic materials of the course. However, in most cases, AI will only change the role of the teacher to the role of facilitator (p. 350).

In short, the idea of teacher replacement never seems to have been explored in depth in the field of AIED. When it is discussed, it's mostly in a peripheral way to assert that it's not possible, with contradictions in terms of the goal pursued (to replace the teacher or not). A few authors do, however, elaborate on the idea of transforming the role of the teacher in the context of the accelerated development of AIED.

Discussion

Analysis of the results shows that the roles assigned to AI in the field of AIED are those that normally fall to the teacher. So, even if the expression *teacher replacement* elicits a number of fears and even if this objective is, for the time being, unattainable, the fact remains that it seems to be one of the scientific ambitions of the field—an ambition all the more difficult to detect as the opposite is sometimes stated. This can be seen in the comments of several authors, who are seeking to model the teacher's role as well as possible, including his or her emotional work and the management of social interactions, to better design AIED systems. Given this observation and the lack of development in the thinking about the transformation of the teacher's role in the context of increasingly complex and widespread AIED, it seems essential to us that educational systems clarify the desired interactions between the different players—the AI, the teacher and the learner. Failing this, there is a risk that new actions needed to regulate learning will be taken neither by the AI nor by the teacher, and that informal actions that have until now been taken by the teacher will be abandoned through gradual delegation to AIED systems.

Some authors have proposed using a teacher-learner-AI triangle to conceptualize roles and their interactions, starting with Cumming *et al.* (1997). According to du Boulay (2021), the study of interactions among those three components has led to a real appreciation of the importance of the teacher in the educational environment. Humble and Mozelius (2019), drawing on several sources, refer to a values problem that can potentially hinder the successful deployment of AIED, for example, when the values that support the development of strong AI are misaligned with those of the people who are to use it, and in this regard evoke the importance of "human-compatible AI" (p. 2). Celik *et al.* (2022) proposed a loop of interactions between teachers and AI in which teachers set assessment criteria, review AI decisions, document technical issues, feed learner data into the systems, and the AI carries out assessments, tracks student progress and informs teachers' planning. As the review brought to light the relationships among AI, teachers, learners and knowledge, we also propose to conceptualize those interactions on the basis of Houssaye's didactic triangle (1988), originally published in 1988 and widely mobilized in the field of education.

The didactic triangle has already been revisited several times to incorporate ICT or the computer, but never to our knowledge to incorporate AI specifically. Faerber (2003) was the first, to our knowledge, to propose an update of the didactic triangle by integrating a technological pole. Essentially, he starts from the observation that the relationships identified by Houssaye (1988) are modified when teaching-learning takes place via a virtual environment: "l'environnement virtuel d'apprentissage est un intermédiaire à la fois fonctionnel, matériel, logiciel entre les pôles" (p. 202). According to Yassine (2010), the role of the computer in the didactic triangle depends on how it is used. It can act as a "ordinateur enseigné", in which case the student programs the computer, as was already the case in Papert's studies with the LOGO learning environment. It can also be a "tuteur", i.e., it leads learners "through a number of trial-and-error steps to help them recognize their shortcomings and acquire knowledge without teacher intervention" (par. 4.1.2). And it can also be an "outil" i.e., instrumentalized by the teacher as a support for certain types of learning, for example, to present information. According to these different ways of looking at the computer, its role is more or less active in the didactic triangle. We propose that AI, as it is conceptualized today, and

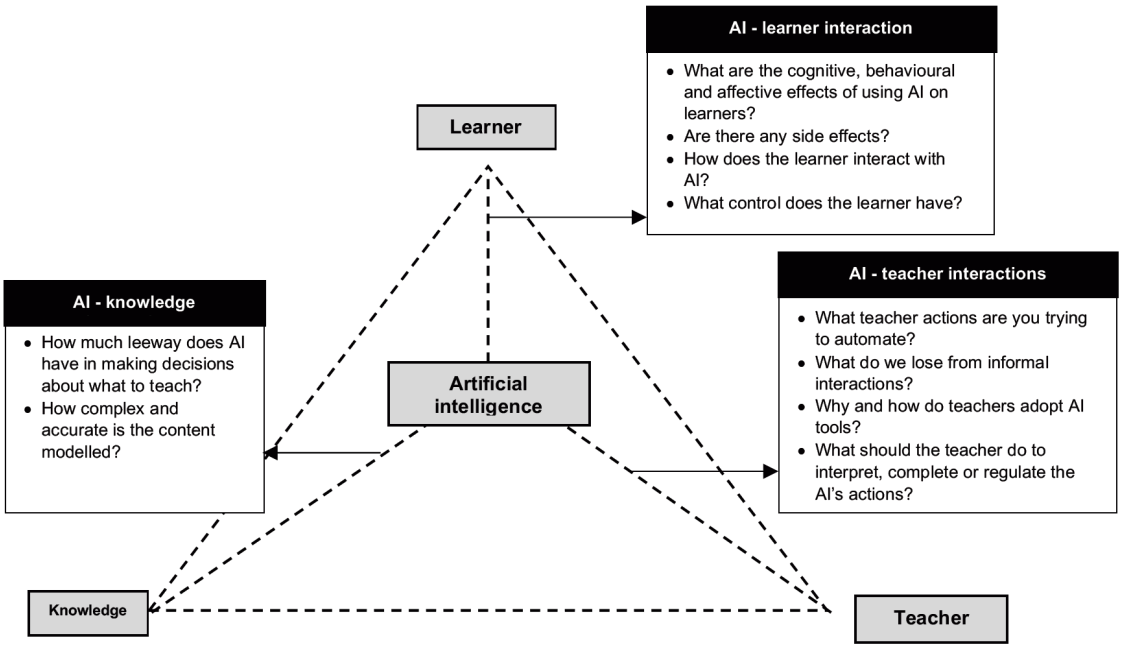
in continuity with research in the field of AIED, aims to play an increasingly active role within the didactic triangle. Indeed, we have observed a gradual shift between the early writings in the field and those of today, with the former talking more about AI systems or software using AI, while the latter speak more generally of artificial intelligence almost giving the impression of personification. AI is less and less seen as passive and instrumental, given the complexity of the decisions it can make. This, incidentally, echoes a distinction made by Wenger (1986) between computer-aided instruction (CAI) and AIED: systems developed in the field of AIED can make instructional decisions without having been specifically programmed to do so, unlike those developed in the field of CAI.

The didactic triangle has also been revisited by Lombard (2007) to develop the ICT tetrahedron. According to Lombard, “le maître en classe est très souvent ignoré ou son rôle minimisé ” (par. 30). In his view, many educational technologies, such as educational games, are often designed without regard for the role of the teachers, and rather with a view to doing something that normally falls to them. In this case, the uses are of the order of “l’alternance [entre le professeur] et le dispositif cyber-prof” (par. 37) and do not fall within the scope of pedagogical integration. Even if we are not talking specifically about AIED tools, the same question can be asked of the latter: should there simply be alternation between the teaching provided by the teacher and that provided by AI, or should there be pedagogical integration of the AI by the teacher? A lack of attention to the desired interactions between a technological device and the teacher can lead to “des conflits sournois” (par. 45), for example, a reduction in the quality of the pedagogical relationship, or even its abandonment by the introduction of an intermediary. On the subject of teacher-device collaboration, Lombard states that “les – plutôt rares – usages des technologies où une collaboration efficace s’établit entre les 2 pôles pédagogiques que nous avons pu observer, semblent majoritairement des usages où le [dispositif] joue un rôle très peu intrusif sur le plan de la relation pédagogique” (p. 23).

We therefore propose to re-use Faerber’s tetrahedron of ICT in education (2003) and re-discussed by Lombard (2007) to examine the new reality arising from the growing permutation of AI in the educational context. Unlike Lombard (2007), we argue that the tetrahedron should not, or should no longer, become entangled in studying uses of computers in the same way, i.e., where they are instrumentalized by the teacher or learner, and those where AI actively transforms the learning situation. At the very least, such uses would be best studied on the edges of the tetrahedron for the mediation they operate on or among actors, but should not occupy a vertex in their own right. In fact, Faerber (2003) explicitly states that he “[n’a pas conféré à l’environnement virtuel] un statut de pôle au même titre que l’apprenant ou le savoir” (p. 202). Explicitly integrating AI at the apex of the tetrahedron devoted to what Lombard calls the “Dispositif Cyber-prof” raises new research questions that have not traditionally been part of the AIED field. These questions, which touch directly on the idea of interaction between teachers and AI, and the confronting idea of replacing teachers with a machine, need to be asked and studied if satisfactory answers are to guide the efforts of teachers and educational systems more generally. The teacher should not continue to do what AI does better, and AI should not be used to do what we don’t yet understand about the teacher’s role.

Figure 5 presents questions that we believe should inform the design of AIED systems, as well as research in the field. Such an approach also involves a move away from seeing AIED systems as tools to aid teaching and learning, and to see them as full players in the process, a change we believe is essential in view of advances made in the field and in preparation for those to come.

Figure 5
Proposed framework for thinking about AI-teacher-learner interactions based on the tetrahedron of ICT in education by Faerber (2003).



Limitations

Despite our efforts to include as many documents as possible by searching several databases and integrating cross-references, it is possible that some relevant documents were not found, particularly those not indexed in digital databases. Document coding was carried out by only one of the authors, but the grid was adjusted by the researchers at working meetings during the analysis process. Finally, as the articles are mainly theoretical, the roles of AI and the teacher are primarily anticipated rather than observed.

Conclusion

This literature review was based on a corpus of 48 documents evoking the role of the teacher in the field of AIED. Through an inductive analysis, it brought to light the relationships among teachers, learners, AI and knowledge as they are conveyed in the field. The main finding is that the roles of the teacher and the learner are given little attention in the field, compared with that of AI. Despite repeated claims that AI is not intended to replace the teacher, the actions delegated to it tend to show that the aims are to automate tasks that normally fall to the teacher (e.g., assessing learners, supporting motivation, providing accurate feedback), even if this ambition is not achievable in the foreseeable future. Given advances in AI and the growing complexity of tasks that can be automated, it seems essential to better conceptualize roles to

ensure that essential teacher tasks that are incompletely modeled are not abandoned to AI (e.g., informal actions that are nonetheless important). Similarly, given the advances in the field of emotion detection and even classroom activity monitoring, it seems essential to further study the effects of replacing the teacher with AI, not only on cognitive aspects, but also on behavioural and affective ones. Based on an adaptation of Houssaye's didactic triangle (1988) and Faerber's ICT tetrahedron (2003), we have proposed questions that could guide research and design in the field of AIED, taking into account the roles of the learner, the teacher and AI.

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