

Applications of AI agents in Education: A Systematic Review Based on Empirical Studies

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Abstract—This study examines the application of AI agents in education through a systematic literature review. Empirical studies published after November 2023 were retrieved and screened from four databases including Web of Science, ERIC, IEEE Xplore, and the ACM Digital Library. Eleven studies were finally retrieved for qualitative analysis. The results show that, as adaptive teaching tools, AI agents can improve learners' academic performance, knowledge transfer, social interaction quality, and emotional experience. Their educational applications span all academic stages and present a spiral pattern of progression. They focus on stimulating interest and conducting basic inquiry in the primary school stage, cultivating complex cognitive skills in the middle school stage, and training advanced professional abilities in the university stage. In terms of design and implementation, AI agents are predominantly centered on conversational interaction and embedded within existing instructional structures. Their functional design is informed by learning theories such as scaffolding and constructivism. These findings synthesize empirical evidence to illuminate the progressive application of AI agents in education.

Keywords—AI Agents, Education, Systematic Review, Generative AI

I. INTRODUCTION

In educational research, an AI agent is defined as a software entity that can perceive learning situations and make decisions based on preset goals and interact with learners continuously [1]. Although early educational intelligent systems partially possess the above basic perception and decision-making abilities, most of them are driven by preset rules or fixed scripts and have not yet formed generative reasoning and dynamic adaptive capabilities. The AI agents concerned in this paper

specifically refer to teaching agents empowered by generative AI technology. They participate in teaching activities in the form of an agent, have core autonomous attributes as well as generative reasoning and adaptive

interaction capabilities, and can provide learners with personalized cognitive support and emotional care [2]. To systematically investigate the practical role of AI agents in education, this study adopts the method of systematic literature review. It aims to explore the effects of AI agents on learners' performance, social interaction and emotional experience, and analyze their differentiated presentation in different educational stages and scenarios as well as the core characteristics of teaching and agent design. This paper carries out analysis around the following three core research questions: (1) What are the impacts of AI agents on learners' learning outcomes? (2) What differences are shown in the teaching of AI agents in different educational stages and scenarios? (3) What main characteristics are presented in the instructional design and agent design of AI agents in educational applications?

II. METHODOLOGY

This study adopts a systematic search strategy and screens literatures according to predefined inclusion and exclusion criteria. The research process follows the guidelines outlined in the PRISMA Statement to ensure the rigor and transparency of the method [3].

A. Search Strategy

Four databases are selected for literature retrieval in this study, including Web of Science, ERIC, IEEE Xplore and ACM Digital Library. The time scope covers articles published after November 2023. The search keywords are defined as the combination of generative AI OR genAI AND Agent AND learning OR education OR pedagogi*. Articles that are not in English, review papers, articles unrelated to AI agents and articles irrelevant to education and teaching are excluded.

B. Study Selection

A total of 148 articles are initially retrieved in this study. After removing 3 duplicate records, 145 articles are finally

obtained. Then, a two-stage screening process is carried out in accordance with the PRISMA method [3]. In the first stage, preliminary screening is conducted based on titles and abstracts to exclude articles obviously unrelated to the research topic. In the second stage, full-text review is performed on the remaining articles to further eliminate those that do not meet the inclusion criteria, and only relevant empirical studies are retained. After these two rounds of screening, 11 empirical research articles are included. Figure 1 shows the selection process of the systematic review, which clearly outlines each stage of literature screening and the reasons for excluding articles.

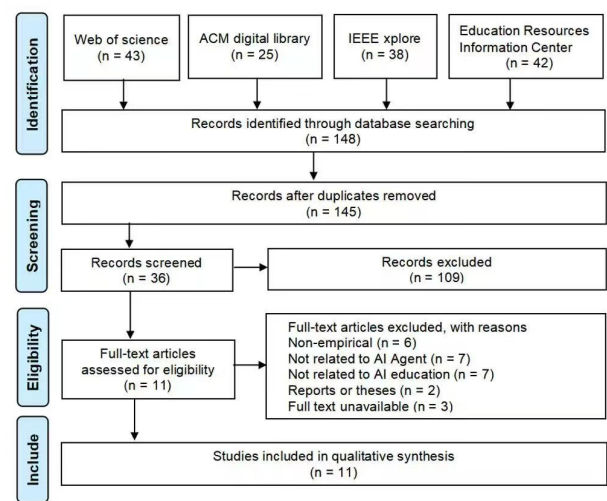


Fig. 1. Flow Chart of Study Selection

C. Data Analysis

This part adopts qualitative analysis method to extract core data and key conclusions about the educational application effects of AI agents, academic stage adaptation strategies and the transformation of teachers' roles from the 11 selected empirical studies.

III. RESULTS

A. The Impact of AI agents on Learners' Learning Outcomes

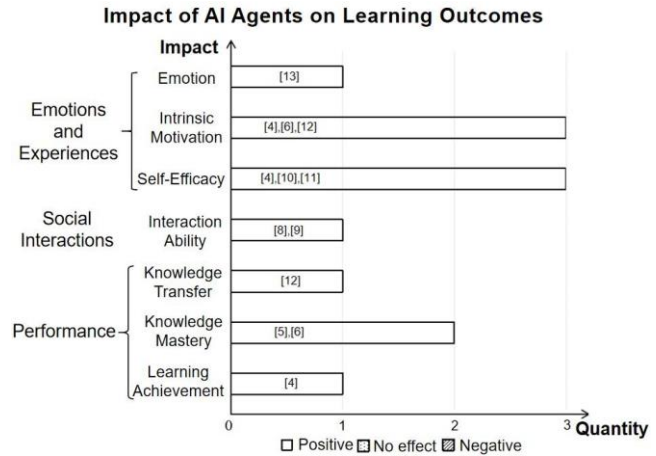


Fig. 2. Schematic Diagram of the Impact of AI agents on Learning Outcomes

As an adaptive teaching tool, the impact of AI agents on learning outcomes has become a research focus in teaching. This study systematically sorts out the mechanism and effect valence of their role on three core outcomes, namely learners' performance, social interaction and emotional experience. The impact of AI agents on learning outcomes is presented in Figure 2 and Table 1.

TABLE I. SUMMARY OF LEARNING OUTCOME TYPES

Outcome	Dimension	Literature	Impact
Performance	Learning		
	Achievement	[4]	P
	Knowledge		
	Mastery	[5], [6]	P
Social Interactions	Knowledge		
	Transfer	[12]	P
	Interaction		
	Ability	[8], [9]	P
Emotions and Experiences	Self-efficacy	[4], [10], [11]	P
	Intrinsic Motivation	[4], [6], [12]	P
	Emotion	[13]	P

Notes: Positive: P; Negative: N; No effects: NE

1) Performance

In terms of performance, it has been confirmed that AI agents can effectively improve learners' academic performance, knowledge transfer ability, mastery of mathematical knowledge and argumentation ability. The study by Wang et al. found that the AI-Agent-supported Collaborative Learning method can provide personalized learning experiences according to individual learner characteristics and thus improve academic performance [4]. Xing et al. verified that learners using ALTER-Math have achieved greater and significant improvement in the mastery of mathematical knowledge [5]. The experiment by Wu et al. showed that the cooperative intelligent agent system has a significant effect on improving mathematical argumentation ability [6]. Song et al. pointed out that when learners study with teachable agent (TA), they faced their own knowledge gaps and misunderstandings [12]. This prompts them to identify the areas that need focused attention, correct misunderstandings and transfer existing disciplinary knowledge to new and more complex problems.

2) Social interactions

In the dimension of social interaction, existing studies generally indicate that agents show positive potential [8]. Dieker et al. found that AI agents are evolving to be more realistic and expressive [9]. They can respond to learners'

emotions through the progress of multimodal data collection, recognition algorithms and signal processing.

3) *Emotions and experiences*

In terms of emotional experience, the advantages of agents are the most significant. Through successful experiences and immediate feedback, agents can effectively improve learners' self-efficacy [4][10][11]. They can also stimulate learning interest and intrinsic motivation through interactive design and role-playing [4][6][12]. The study by Liu et al. pointed out that emotional scaffolding conversational agents can improve learners' emotional state in online learning [13]. The experiment by Song et al. indicated that the interaction between learners and TA has significantly stimulated their intrinsic motivation [12]. In the learning process, learners are given clear sense of responsibility and generate the self-cognition of "I am an expert". After the experience, they show high enthusiasm and engagement in the whole learning process.

B. *Differences in the Teaching Presentation of AI agents Across Different Educational Stages and Scenarios*

The educational application differences of AI agents are reflected in three aspects: academic stages, scenarios and instructional design.

1) *Academic Stage Differences*

The application of AI agents runs through the whole development process of learners and presents obvious characteristics of spiral advancement. The primary school stage focuses on stimulating interest and conducting basic inquiry. For example, Cai et al. pointed out that the intervention of AR-based embodied conversational agents has significantly improved learners' critical thinking, curiosity and learning motivation [15]. The middle school stage focuses on cultivating complex cognitive skills. Xing et al. used ALTER-Math and cooperative intelligent agents, which not only promoted learners' mastery of mathematical knowledge [5], but also effectively improved their mathematical argumentation ability [6]. Undergraduate education emphasizes the development of advanced professional skills, including programming and academic English [4][14].

2) *Application Scenarios*

Application scenarios can be mainly divided into three categories: formal classroom teaching, online autonomous learning and skill simulation training. Most studies regard AI agents as the core or supplementary link of teaching. Some studies have applied them in classroom environments to improve or enhance learners' mastery of disciplinary knowledge and higher-order thinking ability, strengthen learning motivation and participation, and support personalized learning, inquiry-based learning and collaborative problem-solving [5][6][12][15]. Some studies have focused on online or blended learning environments. They provided knowledge and emotional scaffolding through conversational agents to support learners' autonomous learning [10][13]. In addition, the desktop virtual reality constructed by Li et al. created an immersive simulation training scenario for English presentation skills. It placed virtual learners and teaching agents in the same virtual space to improve students' sense of immersion [14].

C. *Main Characteristics of Instructional Design and Agent Design in the Educational Application of AI agents 1) Instructional Design Dimension*

AI agents are usually embedded in the established teaching structure. They support the learning process through teaching theories rather than changing teaching objectives [1]. Wang et al. proposed that in university programming courses, the agent designed based on scaffolding instruction and self-regulated learning theory takes curriculum tasks and collaboration as the core, and supports problem-solving through immediate feedback and prompts [4]. The research by Cai et al. showed that the embodied conversational agent (ECA) virtual scientist designed based on constructivist theory integrates generative artificial intelligence with augmented reality. It continuously guides students to engage in learning through conversational interaction and situational prompts, significantly improves their participation, and promotes the active construction of knowledge in the interaction process [15]. Wu et al. pointed out that the dialogue-based intelligent tutoring system in mathematical argumentation learning is based on cognitive apprenticeship theory. It makes the reasoning process explicit by guiding students to go through the steps of argument generation, verification and summary, and supports the formation of strategies and thinking modes [6].

Xing et al. pointed out that in the design of learning-by-teaching, students reorganize and reflect on knowledge by explaining mathematical concepts to TA. This design is consistent with constructivist and self-regulated learning theories [5]. Liu et al. showed that the conversational agent based on cognitive and emotional scaffolding theory integrates knowledge prompts, emotional feedback and learning progress monitoring into the agent, clarifies the support of different functions, so as to improve students' knowledge acquisition and emotional experience [13]. Undergraduate education emphasizes the development of advanced professional skills, including programming and academic English.

2) *Agent Design Dimension*

The existing research is carried out from two dimensions: interface form and functional logic. The interface form design of AI agents aims to shape the intuitiveness of interaction and the sense of situational integration. It is specifically manifested in various forms such as basic text dialogue interface [4], 3D ECA virtual scientist integrating augmented reality [15], and dual-agent dialogue system simulating real teaching interaction [6]. The design of functional logic focuses on realizing personalized and adaptive support, and its specific implementation mechanisms have different emphases. The AI-Agent developed by Wang et al. integrates semantic memory and episodic memory modules, which can provide targeted code suggestions and solutions according to the history of programming tasks [4]. The ECA constructed by Cai et al. uses prompt engineering to enable the same virtual character to dynamically play the role of different historical scientists, so as to support scientific inquiry dialogue from multiple perspectives [15]. The system designed by Wu et al. adopts a dialogue framework based on "expectations and misunderstandings". It can match and analyze the answers input by students, and provide hierarchical feedback from prompts and hints to direct correction, so as to systematically

guide students to complete mathematical argumentation [6]. Yugo's pedagogical conversational agent takes metacognitive suggestions, knowledge integration promotion and communication encouragement as the core [17]. It generates targeted feedback according to keyword detection and time rules, and adapts to real-time gaze feedback coordination to improve collaboration and learning effects [17]. In addition, the core function of the teachable agent is to simulate learning behaviors. It prompts students to explain and teach by actively asking questions or presenting preset errors [5][12].

IV. DISCUSSION

A. *What Impact Do AI agents Exert on Learners' Learning Outcomes?*

Based on the comprehensive analysis of existing research results, it can be seen that as an adaptive teaching tool, AI agents have a positive impact on learners' learning outcomes in various aspects. At the performance level, studies have confirmed that they can effectively improve academic performance [4], knowledge transfer [12], mastery of mathematical knowledge and argumentation ability [5][6]. The core mechanism lies in helping learners identify and make up for knowledge gaps through personalized learning support. In the dimension of social interaction, with the development of multimodal data and emotion recognition technology, AI agents show increasingly enhanced authenticity and interactive response capabilities, which provides the possibility to create a more supportive learning environment [9]. In terms of emotion and experience, through providing successful experiences, immediate feedback and interactive role-playing, agents have significantly enhanced learners' self-efficacy [4][10][11], intrinsic motivation and learning interest [12], and helped improve the emotional state in online learning [13]. However, most existing studies are based on short-term interventions and small-sample experiments, which are mainly limited by factors such as technology maturity and experimental cost, leading to doubts about the universality of the conclusions [4][6][15]. Therefore, future research needs to carry out longitudinal design, further explore the internal mechanism of AI agents supporting the development of social emotions, and strive to develop more reliable and ethical systems to realize their comprehensive educational potential [16].

B. *What Differences Are Shown in the Teaching Presentation of AI agents in Different Educational Stages and Scenarios?*

Existing literatures show that the teaching application of AI agents presents differentiated characteristics closely related to their educational stages and specific scenarios. In terms of academic stages, their roles and objectives show clear spiral advancement: the primary school stage focuses on stimulating learning interest and basic inquiry ability by using technologies such as embodiment [6]; the middle school stage turns to supporting the cultivation of complex cognitive skills and argumentation ability in subjects such as mathematics [5]; the university stage further applies them to the training of advanced abilities in professional fields such as programming and academic speech [4][14]. In terms of application scenarios,

AI agents are mainly integrated into formal classroom teaching as the core or supplementary link [6][5][12][15]. They are also used in online autonomous learning environments to provide knowledge and emotional support [10][13], or create immersive skill simulation training scenarios in specific situations [14]. Overall, these differences reflect that as a tool, the instructional design and functional realization of AI agents need to be targeted to adapt to the cognitive development level of different learners and the needs of specific teaching objectives [1].

C. *What Main Characteristics Are Presented in the Instructional Design and Agent Design of AI agents in Educational Applications?*

Existing literatures show that the educational role of AI agents is mainly realized through the process support of instructional design, rather than relying on the functional setting of agents as independent teaching subjects. AI agents are usually integrated into instructional designs such as collaborative learning, mathematical argumentation or learning-by-teaching. Their core functions focus on guiding cognitive activities, promoting reflection and supporting learning regulation. This orientation reflects the leading position of teaching theories in the application of agents [4][6][5][12]. On this basis, agent design generally adopts conversational interaction and prompt mechanisms. It realizes process support through the configuration of interface form and functional logic, rather than undertaking the functions of teaching content organization or teaching decision-making [6][14][15]. Furthermore, although there are differences in interface form and technical implementation in different studies, their functional logic all points to personalized and adaptive support, and needs to be consistent with the learning activities and scaffolding structure in instructional design [4][5][6][15]. In general, the significance of AI agents in teaching research should be understood as an instructional design-oriented supporting technology. The effectiveness of their application depends on the degree of coordination between instructional design and agent design, rather than the complexity of the technology itself [7].

V. CONCLUSION

Based on the systematic analysis of 11 empirical studies, this study discusses the application effects of AI agents in education. The results show that AI agents play a positive role in improving learning performance, supporting social interaction and enhancing emotional experience, and can adapt to the differentiated teaching needs of different academic stages. In terms of instructional design, AI agents mostly take conversational interaction as the core and are embedded in the existing teaching structure, reflecting the characteristics of process support and theoretical guidance. However, their long-term impact in actual educational scenarios, adaptability to different learner groups, and professional support required for teachers to integrate agents still need to be further explored. On the basis of the existing research, future research should further focus on the systematic integration of agents and teaching scenarios, strengthen their empirical testing in real classroom environments, and pay attention to the related instructional design training and ethical considerations, so as

to promote the sustainable development and effective integration of their educational applications.

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