

# Multi-agents in Education: A Systematic Review

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**Abstract**—Agent is an adaptive system that can perceive the environment and act upon it to achieve its goals. It provides learners with efficient and convenient learning feedback support, creating vivid and authentic learning environments and experiences. Multi-agents consist of multiple autonomous agents that complete complex tasks through collaboration and communication. In recent years, the advancement of Large Language Models has driven the application of multi-agents in the field of education. This study aims to analyze the current application status of multi-agents in the field of education through a systematic literature review. Data were collected from two databases: Web of Science and IEEE Xplore. The study analyzed 18 selected articles from a qualitative perspective. The results show that multi-agents provide a significant technological path for the digital transformation of education. Their core value lies in optimizing teaching processes and performance through human-machine collaboration. However, potential risks remain, such as technical limitations and weak scenario generalization capabilities, which bring challenges to the application of multi-agents in education. These findings reveal the current application status and lay a foundation for future research.

**Keywords**—multi-agents, education, systematic review, large language models

## I. INTRODUCTION

In recent years, Large Language Models (LLMs) have shown great potential in reasoning and planning. In certain tasks and domains, their performance has reached a level comparable to human reasoning abilities [1]. Building on these advances, LLM-based agents have attracted increasing attention as a promising research in the field of education [2].

An agent is a system situated within an environment that perceives its surroundings and acts upon them over time. It pursues its own agenda and affects what it senses in the future [3]. Owing to these characteristics, agents have been increasingly adopted in educational contexts, where they can

provide learners with efficient and convenient feedback support and help create vivid and authentic learning environments and experiences [4]. However, when operating as single agents, their flexibility and dynamic adaptability remain limited in complex and evolving environments. For example, single agents can only provide fixed scenarios, and this restricts student participation and dialogue [5]. This limits the development of learners' higher-order cognitive abilities and is not conducive to stimulating deep thinking [6]. Therefore, multi-agents have emerged. Multi-agents consist of multiple autonomous agents that collaborate and communicate to accomplish complex tasks [7]. Multi-agents show great application potential in the field of education [8]. Relevant studies indicate that multi-agents can serve as intelligent assistants to solve complex problems in the teaching process [9]. They can also promote personalized learning and simulate specific multi-person scenarios. However, the specific application modes of multi-agents in current educational practice are not yet clear.

Therefore, this study aims to systematically understand the current application status and future research directions of multi-agents in the field of education. Specifically, it focuses on the following research questions: (1) What are the characteristics of the research publications? (2) How are multi-agents designed in specific studies? (3) What are the application scenarios of multi-agents in education? (4) What is the impact of multi-agents on teaching and learning?

## II. METHODS

To ensure the scientific nature of the research and the accuracy of data sources, this study selected literature strictly according to predetermined inclusion and exclusion criteria. The literature review process was conducted based on the recommendations of the PRISMA statement [10].

### A. Search Strategy

This study searched the Web of Science and IEEE Xplore databases for literature published between January 1, 2022, and November 30, 2025. The keyword "Multi-Agents" was used as the title search term. "education OR learning OR teaching" and

This work was supported by the Research Projects of the National Natural Science Foundation of China under Grant [62377039]; and 2025 Shaanxi Normal University Graduate Education Comprehensive Reform Research and Practice Project under Grant [GERP-25-01].

“educational Multi-agents OR pedagogical Multi-agents OR tutoring Multi-agents OR virtual Multi-agents OR conversational Multi-agents” were used as Topic search keywords. A total of 351 articles were retrieved.

### B. Literature Selection

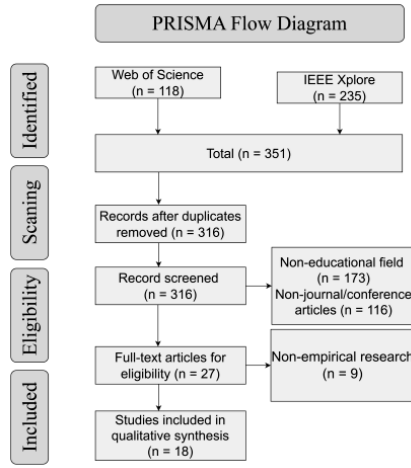


Fig. 1. Literature screening process

Figure 1 shows the entire literature screening process. The exclusion criteria included non-educational fields, non-empirical studies, and non-journal or non-conference articles. 35 duplicate entries were removed, leaving 316 articles. Then, researchers conducted a two-stage screening of the remaining articles according to the exclusion criteria. After two rounds of screening, 299 articles were removed for not meeting the criteria. Finally, this study included 18 articles that met the requirements.

### C. Data Analysis Methods

This study used qualitative analysis methods to address the research questions. This mainly involved using visualization charts to describe publication characteristics and describing specific research findings.

## III. FINDINGS

This section mainly describes the results of the study. To systematically integrate and evaluate the application effectiveness and advantages of multi-agents in existing literature, the specific information of the 18 articles is organized in Table I.

TABLE I. LITERATURE INFORMATION

| ID | Author             | Development Platform         | Technological                                        | Collaboration Mode | Role-Playing | Timing of Intervention | Application Scenarios | The Impact on Teaching and Learning                                    |                                                                                        |
|----|--------------------|------------------------------|------------------------------------------------------|--------------------|--------------|------------------------|-----------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
|    |                    |                              |                                                      |                    |              |                        |                       | Positive                                                               | Challenge                                                                              |
| 1  | Aleedy et al.      | streamlit                    | AI models, fine-tuned GPT model, hybrid architecture | P                  | TI           | D                      | LTL                   | enhances learner engagement, motivation, and self-assessment           | contextually unexpected retrieval results, rigid evaluation criteria                   |
| 2  | Li et al.          | squirrel ai learning         | llama-3, mixtral, GPT                                | SH                 | RPM          | T                      | ALKM                  | improves efficiency and scalability                                    | recall decreased, false negative errors increased                                      |
| 3  | Kocher et al.      | not explicitly specified     | non-humanoid collaborative robot system              | P                  | LC           | D                      | CSSD                  | increased motivation                                                   | need larger sample size for reliability                                                |
| 4  | Carvalho et al.    | not explicitly specified     | not explicitly specified                             | P                  | RPM          | D                      | CSSD                  | provides task assistance                                               | evaluation by experienced users only                                                   |
| 5  | Cai et al.         | not explicitly specified     | local LLM                                            | C-C                | ADS          | A                      | TALA                  | enhances efficiency                                                    | limited to English context                                                             |
| 6  | Shi et al.         | ModelScope-Agent             | LLM                                                  | HS                 | LC           | D                      | LE                    | enhances higher-order cognitive skills                                 | limited by sample size, short duration, self-report bias, technical limitations in NLP |
| 7  | Rehm et al.        | unity gaming engine          | not explicitly specified                             | HS                 | TI           | D                      | VE                    | personalized real-time feedback                                        | discontent with the feedback, technical limitations                                    |
| 8  | Tebourbi et al.    | React.js, FastAPI, LangGraph | BPMN,MAS, RAG                                        | SH                 | TI           | D                      | LTL                   | delivers faithful, relevant responses with high satisfaction           | proprietary model dependencies, human validation bottleneck, scalability challenges    |
| 9  | Garcia et al.      | NetBeans IDE 8.1             | Google Maps API, GPS sensor                          | SH                 | ADS          | D                      | CSPL                  | provides personalized, context-aware support for learning              | limited sensor integration, only GPS used                                              |
| 10 | Yu et al.          | Python Agent Development     | LLM                                                  | HS                 | TI           | D                      | CSPL                  | improves correction accuracy and success rate while reducing time cost | over-simplified E-RL parameter selection                                               |
| 11 | Cruz Garcia et al. | PANGEA                       | LIDAR sensors, Robot Operating System                | ET                 | RPM          | D                      | SE                    | high educational potential and user acceptance                         | limited gesture interaction, small-scale initial user study                            |

| ID                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Author         | Development Platform                             | Technological                    | Collaboration Mode | Role-Playing | Timing of Intervention | Application Scenarios | The Impact on Teaching and Learning                                                             |                                                                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------------------------------------|----------------------------------|--------------------|--------------|------------------------|-----------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                |                                                  |                                  |                    |              |                        |                       | Positive                                                                                        | Positive                                                                       |
| 12                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Xiao et al.    | not explicitly specified                         | Blockchain                       | SH                 | RPM          | T                      | ALKM                  | improves scores and engagement, enables personalization                                         | risks undermining teacher role, faces high computational costs                 |
| 13                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Shahzad et al. | Google Colab                                     | NLP techniques                   | ET                 | ADS          | A                      | SE                    | high assessment accuracy                                                                        | no real-time feedback yet                                                      |
| 14                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Rida et al.    | Java Agent Development Framework                 | not explicitly specified         | HS                 | RPM          | D                      | ALKM                  | boosts academic performance and engagement, reduces dropout rates through personalized tutoring | may have slow response under load, and has limited generalizability            |
| 15                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Li et al.      | not explicitly specified                         | graph-based knowledge navigation | HS                 | TI           | D                      | SE                    | enhances performance in explaining concepts, fostering cross-disciplinary links                 | coordination delays, and high computational demands                            |
| 16                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Du et al.      | not explicitly specified                         | not explicitly specified         | N                  | LC           | D                      | SE                    | fosters critical and dialectical thinking, improving understanding                              | cannot replicate human teacher's depth, and is constrained by technical limits |
| 17                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Hu et al.      | Seed Studio XIAO ESP32S3 Sense development board | LLM                              | HS                 | ADS          | A                      | TALA                  | saves note-taking time and aids teaching plan optimization                                      | terminology recognition accuracy, and needs interface refinement               |
| 18                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Liu            | not explicitly specified                         | not explicitly specified         | SH                 | RPM          | T                      | LTL                   | enhances resource integration                                                                   | not explicitly specified                                                       |
| <b>Note:</b><br>Collaboration Mode: (1) HS = hierarchical structure; (2) SH = sequential handover; (3) P = parallel; (4) ET = expert team; (5) N = negotiation; (6) C-C = criticism - critic<br>Role-Playing: (1) TI = teaching instructor; (2) LC = learning companion; (3) RPM = resource and process manager; (4) ADS = assessment and diagnostic specialist<br>Timing of Intervention: (1) T = throughout the teaching/learning process; (2) B = before the teaching/learning process; (3) D = during the teaching/learning process; (4) A = after the teaching/learning process<br>Application Scenarios: (1) SCPL = computer science and programming learning; (2) LTL = language and translation learning; (3) SE = STEM education; (4) VE = vocational education; (5) CSSD = collaborative and social skills development; (6) TALA = teaching assessment and learning analytics; (7) ALKM = adaptive learning and knowledge management; (8) LE = legal education |                |                                                  |                                  |                    |              |                        |                       |                                                                                                 |                                                                                |

#### A. What are the Characteristics of the Research Publications?

##### 1) Distribution of Publication Years

As an important research field, multi-agents appeared as early as the 1980s as a branch of distributed artificial intelligence. However, after the rise of LLMs, multi-agents have shown better application effectiveness. For example, early multi-agents only executed deterministic tasks. After applying LLMs, the development and application thresholds were reduced. They can also play complete roles such as teachers and domain experts, evolving into multi-agents with a certain degree of autonomy and versatility. Therefore, this study focuses on literature of multi-agents in education published after 2022.

Among these 18 eligible publications, 1 article was published in 2022. Since then, there was a small increase in 2023 (n = 2) and 2024 (n = 4). In 2025, the growth trend rose significantly (n = 11). This phenomenon indicates that the application of multi-agents in education has entered a productive period. It has injected strong power into promoting educational reform.

##### 2) Main Publication Sources and Journal Information

Among the 18 publications, there were 12 journal articles and 6 conference articles. Applied Sciences had the most publications, with 3 articles. This was followed by IEEE Access, with 2 articles. The remaining sources had 1 publication each. Specific information is shown in Table II. It includes core journals in the field of educational technology, high-level

journals and conferences in computer science and artificial intelligence, as well as comprehensive journals and conferences.

TABLE II. JOURNAL/CONFERENCE PUBLICATION INFORMATION

| Journal/Conference                                                                   | Number of publications |
|--------------------------------------------------------------------------------------|------------------------|
| Applied Sciences                                                                     | 3                      |
| IEEE Access                                                                          | 2                      |
| 2023 IEEE Frontiers in Education Conference                                          | 1                      |
| 2024 7th Iberian Robotics Conference                                                 | 1                      |
| 2024 Artificial Intelligence x Humanities, Education, and Art                        | 1                      |
| 2024 IEEE International Conference on Big Data                                       | 1                      |
| 2025 IEEE 3rd International Conference on Image Processing and Computer Applications | 1                      |
| Advances in Multimedia                                                               | 1                      |
| AI Magazine                                                                          | 1                      |
| Education and Information Technologies                                               | 1                      |
| Frontiers in Artificial Intelligence                                                 | 1                      |
| Information                                                                          | 1                      |
| Interactive Learning Environments                                                    | 1                      |
| The Thirty-Ninth AAAI Conference on Artificial Intelligence                          | 1                      |
| World Journal on Educational Technology: Current Issues                              | 1                      |

#### B. How are Multi-agents Designed in Specific Studies?

##### 1) Technological Choices in multi-agents Design

An analysis of the technical choices in the 18 studies reveals main characteristics in the development of multi-agents. At the

development level, systems mainly rely on professional frameworks including JADE and PANGAEA. At the core level, LLMs like GPT, are widely used as the core for understanding and generation. At the interaction level, online applications mostly rely on cloud-based API services, while offline embodied environments require hardware facilities like sensors.

In summary, it can be seen that using LLMs and various technologies as the core to enhance reliability and effectiveness, selecting a reasonable framework for collaboration, and finally applying them to various scenarios has become a trend in most studies. The use of technology is diverse, but the goal is always to serve educational scenarios.

## 2) Collaboration modes among multi-agents

Referring to the standards for collaboration modes among multi-agents (6 types) in Antonio Gulli's *Agentic Design Patterns - A Hands-On Guide to Building Intelligent Systems*, the proportions of collaboration modes in the 18 articles are: hierarchical structure ( $n = 6$ ), sequential handover ( $n = 5$ ), parallel ( $n = 3$ ), expert team ( $n = 2$ ), negotiation ( $n = 1$ ), and criticism-critic ( $n = 1$ ) [11]. According to the proportions, the collaboration modes of multi-agents applied in education are mostly hierarchical structure and sequential handover. Furthermore, it is found that the workflows of these two collaboration modes are quite similar to the traditional instructional design process. To illustrate these collaboration modes, we present six reference flowcharts in Figure 2, which were constructed based on Antonio Gulli's definition of collaboration modes [11].

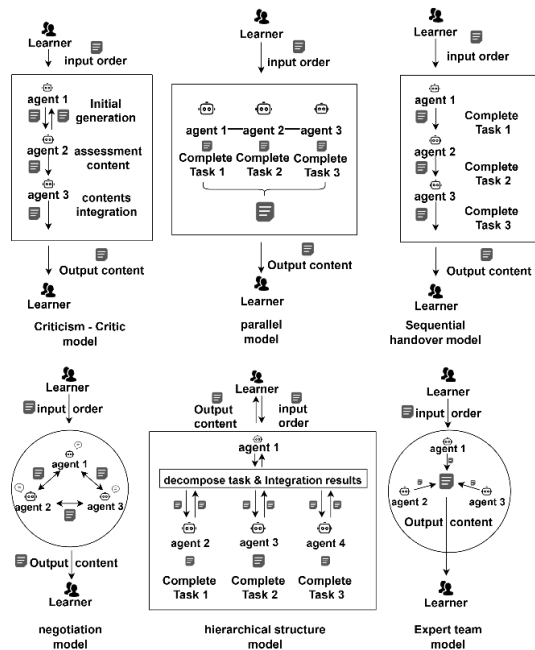


Fig. 2. Workflow reference diagrams of six collaboration modes [11]

## 3) Roles of multi-agents in Practical Applications

Referring to the roles of chatbots interconnected with students in the article by Kuhail et al., such as teaching agents, peer agents, teachable agents, and motivational agents [12], the roles of multi-agents in practical applications are organized into

four categories: (1) Teaching instructor. For example, Rehm et al. provided real-time personalized skill assessment and virtual coach multi-agents. These provide students with real-time, personalized feedback and support the scaling and standardization of teaching [13]. (2) Learning companion. For example, Shi et al. developed law simulation court training multi-agents, they interact with students through multi-role playing and significantly improve students' higher-order cognitive skills [14]. (3) Resource and process manager. For example, Liu's multi-agents facilitated the intelligent collection, integration, and optimal allocation of English teaching resources [15]. (4) Assessment and diagnostic specialist. For example, Shahzad et al.'s multi-agents achieved the automatic assessment of students' cognitive abilities based on Bloom's Taxonomy [16].

## 4) Timing of multi-agents intervention in instruction

Through an analysis of the "timing of intervention" of the 18 multi-agents in the teaching process, it was found that most interventions occurred during the teaching/learning process ( $n = 12$ ). Some interventions occur throughout the teaching/learning process ( $n = 3$ ) and after the teaching/learning process ( $n = 3$ ). However, there are no multi-agents specifically used before the teaching/learning process yet. Thus, existing studies mostly position multi-agents as auxiliary tools during the teaching process or for assessment and analysis after teaching. In the future, more multi-agents should be designed to be used throughout the teaching/learning process. This will support the complete process of teaching, including teaching, learning, management, and assessment, thereby promoting multi-agents from auxiliary tools to partners in collaborative (embodied) learning.

## C. What are the Application Scenarios of Multi-agents in Education?

An analysis of the 18 studies reveals that multi-agents are mainly applied in the following 8 scenarios: (1) Computer science and programming learning ( $n = 2$ ). For example, Garcia et al. presented a context-aware ubiquitous learning system based on multi-agents. They verified system functions through case studies of computer science students from different universities [17]. (2) Language and translation learning ( $n = 3$ ). For example, Aleedy et al. developed real-time practice and feedback multi-agents for English-Arabic bidirectional translation [18]. (3) STEM education ( $n = 4$ ). For example, Li et al. constructed graph-based knowledge navigation coordination professional multi-agents. These perform excellently in university physics education scenarios [19]. (4) Vocational education ( $n = 1$ ). For example, Rehm et al. implemented real-time personalized skill assessment and virtual coach multi-agents [13]. (5) Collaborative and social skills development ( $n = 2$ ). For example, Kocher et al. constructed prosocial multi-agents, they assist children in collaborating on tasks of connecting trees and healing trees [20]. (6) Teaching assessment and learning analytics ( $n = 2$ ). For example, Shahzad et al. designed multi-agents that can evaluate students' text answers, they give corresponding grades [16]. (7) Adaptive learning and knowledge management ( $n = 3$ ). For example, Rida et al. constructed dynamic personalized multi-tutor support multi-

agents [21]. (8) Legal education ( $n = 1$ ). For example, Shi et al. introduced law simulation court training multi-agents [14].

Stacked chart of the roles and application scenarios of multi-agents was drawn, as shown in Figure 3. It reveals a clear “function-demand” matching relationship between role selection and application scenarios. Teaching instructors are mostly used in scenarios with a primary demand for knowledge

or skill transfer, such as language and translation learning and stem education. Learning companions are mostly used in collaborative and social skills development. Resource and process managers are mostly used in adaptive learning and knowledge management scenarios. Assessment and diagnostic specialists are mostly used in teaching assessment and learning analytics.

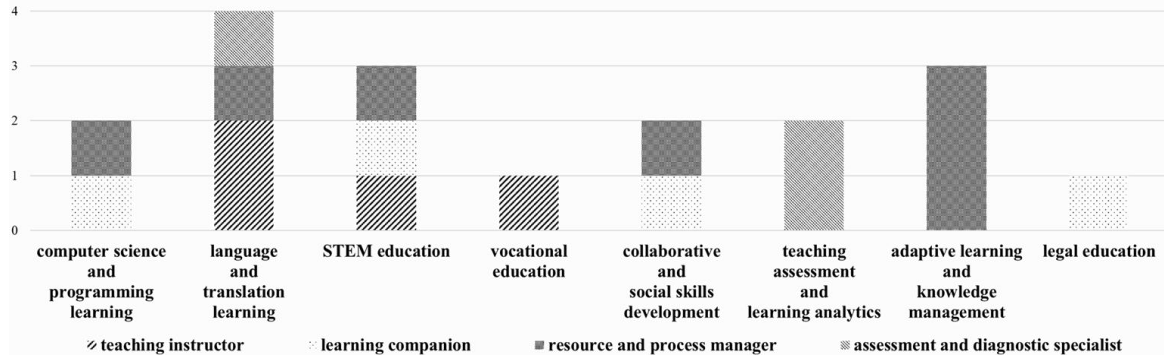


Fig. 3. Stacked bar chart of roles and application scenarios

#### D. What is the Impact of Multi-agents on Teaching and Learning?

Based on the analysis of the 18 articles, it was found that the impact of multi-agents in the teaching process shows significant dual characteristics. They demonstrate great potential in improving learning performance, efficiency, and experience. However, their depth and breadth of application are still limited by current technology levels and research scope.

The positive aspects are mainly manifested in four areas: (1) In terms of learning experience and outcomes, they can effectively improve learner engagement, significantly enhance learner performance, and promote the development of higher-order cognitive skills. For example, the intelligent multi-tutoring system by Rida et al. significantly improved student engagement, motivation, and academic performance, and halved the dropout rate [14]. (2) Teaching and learning processes and efficiency, through automated analysis and assessment and providing appropriate learning resources, teaching and learning efficiency can be significantly improved. For example, the multimodal educational mentor and optimisation system by Hu et al. achieved a 95% satisfaction rate for content retrieval efficiency. The helpfulness of the system was also recognized by the majority, with 77% very or quite satisfied [7]. (3) System performance and technical advantages, the systems can demonstrate high accurate capabilities and stable performance in processing data, showing advantages over traditional teaching methods in tasks such as knowledge labeling. For example, Li et al. applied knowledge tagging with LLM based multi-agents, and this application reduced manual labeling costs by more than 90% [19]. (4) Personalized and adaptive design, they can provide real-time personalized feedback and assessment, promoting the transition from large-scale teaching to personalized growth. For example, Shahzad et al. utilized multi-agents for students' cognitive assessment in E-Learning environments, and these effectively identified students' cognitive strengths and weaknesses and achieved a 92% accuracy rate [16].

However, the limitations and challenges of multi-agents in teaching and learning are also worth noting. They are mainly manifested as: (1) Technical limitations, for example, insufficient technology flexibility leads to a lack of naturalness and humanization in the functional design of multi-agents, thereby affecting the learner experience [13]. (2) Evidence supporting the effectiveness of multi-agents is slightly weak. For instance, most studies have small sample sizes and short experimental cycles, lacking investigations into the effects of large-sample and long-term experiments [20]. Experimental scenarios are also mostly limited to single subjects, so the universality of multi-agents remains to be proven [15].

Therefore, future research should focus on breaking through technical limitations, carrying out large-scale and long-term experimental designs, and promoting the generalization of application scenarios and improve scalability. We should deeply explore the best practices for human-machine collaboration to achieve the optimization of teaching processes and performance.

## IV. LIMITATIONS AND IMPLICATIONS

### A. Limitations

Although this review strives to better explore the application of multi-agents in education, there are still some limitations. For example: (1) The included literature is mainly in English, and the sources are concentrated in two databases, resulting in a limited number of included articles. In the future, literature from multiple databases and languages should be searched to better ensure the completeness of the included research. (2) The included studies are mostly small-scale and short-term experiments, so the validity and feasibility of their conclusions when extended to large-scale and long-term applications remain to be verified. (3) The development of applications for multi-agents in education is extremely rapid. This review is mainly based on literature from January 1, 2022, to November 30, 2025. Future analysis should be conducted on studies that may emerge after this time point.

## B. Implications

With the development of technology, research related to LLMs, AI, and single-agent driven multi-agents has surged. Especially in 2025, there was a significant growth in research on the application of multi-agents in education. However, as noted by Lachheb et al. in their review of AI in higher education, some studies may compromise rigor in the rush to keep pace with emerging technologies, exhibiting a risk of “bandwagon research” [22]. Therefore, multi-agents research in education should aim to guard against “bandwagon” tendencies and to prioritize solving actual educational problems.

In research, while pursuing technological innovation and theoretical support, we should also consider more how to better achieve human-machine collaboration. This will promote the application of multi-agents in education from simply being added to the educational process to being perfectly integrated into it. This provides support for ultimately realizing technology-enabled education.

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